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IDENTIFIERS Military Curriculum Project

ABSTRACT

These individualized, self-paced student texts and workbooks for a secondary-postsecondary-level course in telephone equipment installation and repair is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. Purpose stated for the course is to provide the student with information about electrical fundamentals, transistors, telephony and telephone systems, and telephone station installation, testing, and maintenance. The four-volume course consists of four texts with reading assignments: Introduction (2 chapters), Telephone Construction and Repair (3 chapters), Substation Installation (5 chapters), and Key Systems and Intercommunications (6 chapters). The four volumes of the student workbook correspond with the volumes of the text. Each workbook contains objectives, a study reference guide, and chapter and volume review exercises with answers. (YLB)

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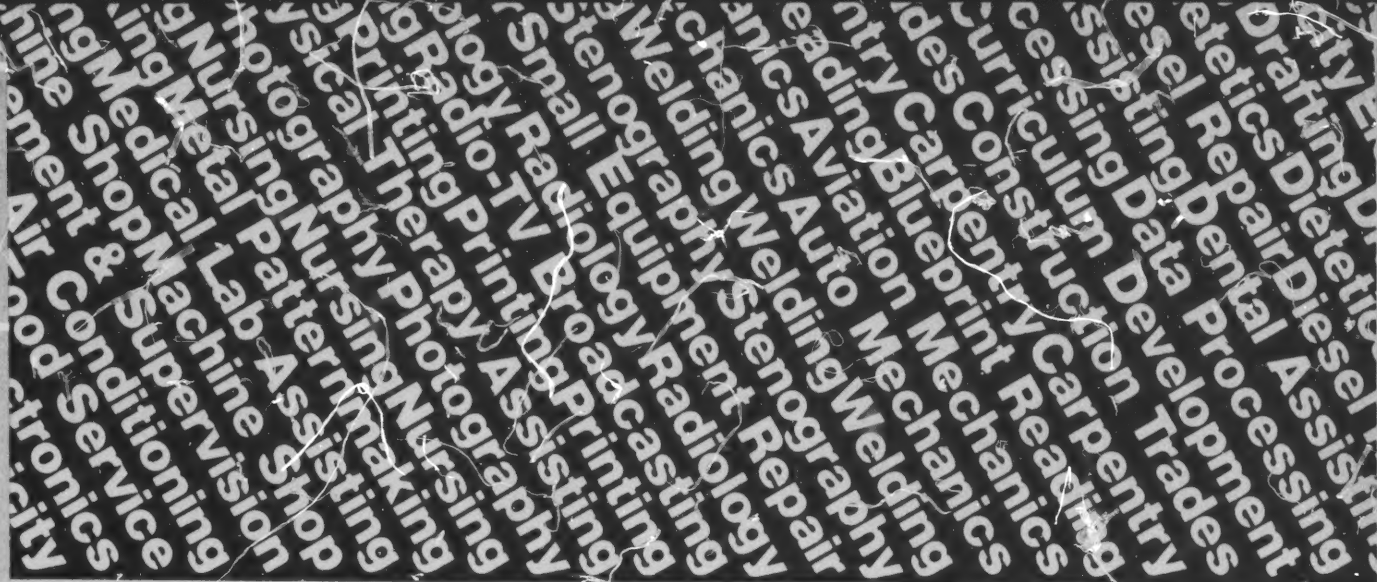
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StenographyRadiology Broadcasting
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gRadio-TV Printing Photography
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otographyNursing Patternmaking
gNursing Patternmaking Assisting
ingMetal Lab Assisting Shop
ngMedical Machine Supervision
hine ShopMachine Conditioning
ement & Supervision Service
Air Conditioning Electronics
Food Service
ctronics
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Military Curricula for Vocational & Technical Education

CE 024 387

TELEPHONE EQUIPMENT INSTALLER-REPAIRMAN

5-4

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

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This military technical training course has been selected and adapted by the Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

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- Developing educational programs and products
- Evaluating individual program needs and outcomes
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- Operating information systems and services
- Conducting leadership development and training programs

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Program Information Office
The National Center for Research in Vocational Education
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
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225 West State Street
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1776 University Ave.
Honolulu, HI 96822
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TELEPHONE EQUIPMENT INSTALLER-REPAIRMAN **Correspondence Course**

CDC 36254

Developed by:

United States Air Force

Development and Review Dates:

October 1974

Occupational Area:

Electronics

Print Pages: 500

Microfiche: 9

Availability:

Vocational Curriculum
Coordination Centers

Suggested Background:

None

Target Audiences:

Grades 10 - Adult

Organization of Materials:

Student texts and workbooks with objectives, study reference guide, review exercises and answers.

Type of Instruction:

Individualized, self-paced

Type of Materials:		**No. of Pages:**	**Average Completion Time:**
Volume 1			
Chapter 4	Fundamentals of Electronics	17	Flexible
Chapter 5	Telephone Fundamentals	16	Flexible
Volume 2			
Chapter 1	Station Equipment for Common-Battery Systems	9	Flexible
Chapter 2	Station Equipment in Automatic Systems	23	Flexible
Chapter 4	Telephone Station Maintenance, Troubleshooting and Repair	18	Flexible
Volume 3			
Chapter 1	Station Planning and Installation Work Procedures	19	Flexible
Chapter 2	Terminal to Telephone Wiring	29	Flexible
Chapter 3	Station Termination and Testing	13	Flexible
Chapter 4	Selective Ringing and Extensions	12	Flexible
Chapter 5	Station Trouble Isolation	12	Flexible
Volume 4			
Chapter 1	Introduction to Key Systems and Intercommunications	13	Flexible
Chapter 2	Operating Principles of Key System Equipment	20	Flexible
Chapter 3	Installation of Key Telephone Systems	4	Flexible
Chapter 4	Maintenance and Testing of Key Telephone Systems	12	Flexible
Chapter 5	Intercommunication Systems	7	Flexible
Chapter 6	Maintenance of the 302 Switching Unit	23	Flexible
Student Workbook			

Supplementary Materials Required:

None

Course Description:

The course is designed to provide the student with information about electrical fundamentals, transistors, telephony and telephone systems, and telephone station installation, testing, and maintenance. The course consists of four volumes:

Volume 1 -- Introduction has an explanation on electrical fundamentals and trouble analysis. Fundamentals of telephony are also explained.

Volume 2 -- Telephone Construction and Repair explains both manual and automatic systems, the basic principles of central office switching, and describes telephones and telephone components. Information about telephone troubleshooting, maintenance, and repair is included.

Volume 3 -- Substation Installation presents information on the materials and attachments used in connecting telephones and station apparatus.

Volume 4 -- Key Systems and Intercommunications describes the varied uses and operating principles of exemplary key and intercommunicating systems.

Each volume contains reading assignments. The four volumes of the student workbook correspond with the volumes of the student text. Each student workbook contains review guides, plus chapter and volume review exercises. The course is designed for student self-study.

Telephone Equipment Installer--Repairman
CDC 36254

Correspondence Course

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Topic	Text	Workbook
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Substation Installation	95	375
Key Systems and Intercommunications	179	438

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CDC 36254

TELEPHONE EQUIPMENT INSTALLER-REPAIRMAN

(AFSC 36254)

Volume 1

Introduction to the Career Field

Prepared by Sheppard Air Force Base, Texas, Air Training Command

Extension Course Institute, Gunter Air Force Base, Alabama

Extension Course Institute

Air University

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Preface

AN EFFICIENT telephone equipment installer-repairman understands the theory of electrical and telephone circuitry and the normal functions of telephone station equipment. This knowledge permits him to make rapid analyses of probable troubles.

This CDC is used for home study to increase your knowledge about your career field. Using it in conjunction with the on-the-job training prepares you for undertaking more complex tasks. You will find that these complex tasks often consist of many simple duties which are not difficult to complete. This dual-channel (CDC and learn-by-doing) training can be done while you are helping your organization to perform its mission.

For you, this course may be only a review, but for some it is an introduction to the telephone equipment installer-equipment ladder. It presents information about electrical fundamentals, transistors, telephony and telephone systems, including descriptions of telephone circuits which are representative of subsets, key telephones, and interoffice communications systems. In addition, it provides information about telephone station installation, testing and maintenance. Supervision and management is also covered briefly.

This volume is the first of four volumes. It includes information about career field duties and responsibilities, the specialty training standard, prerequisite qualifications for progression, fundamentals of management and supervision, and security. Further, it has an explanation on electrical fundamentals and trouble analysis. Fundamentals of telephony are also explained.

At the end of this volume is a glossary, which defines many terms or words that are related to your job. Regular reference to it will often provide you with a quick understanding. The appendix is your specialty training standard, which is annotated to give reference to the specific tasks and the applicable chapters and volumes which have information about them. In a separate booklet are review exercises for the chapters and volume.

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NOTE: CHAPTERS 1-3 HAVE BEEN DELETED DUE TO MILITARY SPECIFIC MATERIALS.

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CHAPTER 4

Fundamentals of Electronics

AS YOU PERHAPS concluded from Chapter 1, the installer-repairman is concerned primarily with the installation, maintenance, and operation of telephone communications equipment. To do your job in these areas, it is necessary that you have an understanding of how the equipment operates. Since this equipment is electrical, we will explain that portion of electrical theory which is necessary for a clear understanding of the operating principles. Let's talk about electricity as it is used in telephony.

2. Our discussion will include electron theory of matter; electrical symbols; distribution of voltage, current, and resistance (including calculations in series resistive, parallel resistive, series-parallel resistive, and resistive bridge circuits); magnetism; sources of electrical energy; and electromagnetic devices. We conclude the chapter with information about trouble analysis.

9. Electron Theory of Matter

9-1. According to the electron theory, all physical materials are composed of atoms. Each atom consists of a positive nucleus with one or more negative charges (electrons). The electrons revolve around the nucleus. The atom of one element differs from the atom of another element because it has either fewer or more electrons around the nucleus. Thus, the charges of the two atoms are different. For an atom to be in balance, the quantity of positive charge on its nucleus must equal the quantity of negative charge provided by the electrons. An atom that loses an electron is unbalanced: it now has a greater positive charge since part of the negative charge has been lost. Such an atom (positively charged) has an attraction for negative electrons and for the negatively charged atoms. Conversely, an atom with more electrons than normal is also unbalanced. But, it is negatively charged and seeks a positively charged atom. In the resident course, you learned the basic electrical law that applies to this condition: unlike charges of electricity attract each other, and like charges of electricity repel each other.

9-2. A battery is a unit which is electrically charged. It is connected to a circuit consisting of predetermined electronic devices. Since the positive terminal of this battery has a shortage of electrons and the negative terminal has an excess number of electrons, electrons flow from the negative terminal through the circuit to the positive terminal. The number of electrons that pass through the circuit within a certain period of time is determined by the electronic devices and by the strength of the electrical charge at the source. You learned that this relationship is spoken of as Ohm's law. Further discussion about this law is provided in Section 12.

9-3. You recall that, according to this law, the amount of electrons flowing in the circuit is, at any given time, determined by dividing the resistance into the voltage (I = E/R). This electric current is measured in amperes (milliamperes or microamperes). One effect of current in a circuit is the creation of a magnetic field. Under certain conditions, current also produces light and heat. The effects that result from electron movement are basic to the operation of the telephone system. A telephone system uses relays which operate because of a magnetic field. It has alarms which also operate because of magnetic effects. The alarms are noticed because of lamps which operate as a result of current heating effects. Lamps also are supervision devices on switchboards. Heat is necessary for keeping a system dry, yet is unwanted when it is excessive. Electron flow can produce a chemical action. However, this effect is of limited value for our discussion. We are more concerned that you remember that a chemical action affects the telephone system. You learned that each telephone system includes a battery. A battery is a unit that produces electricity from a chemical action. Electrons flow in the electrolyte from the positive terminal to the negative terminal as a result of this chemical action. Corrosion, which results from chemical action, is harmful to telephone system components.

10. Electrical Terms and Electrical Symbols Review

10-1. A technician in any career field that

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includes electrical equipment can speak fluently with men in his and in allied fields. During their discussions, they use *terms* that are job related. The technician will use electrical *symbols* when presenting a circuit, since they simplify the presentation and permit a more rapid understanding of the circuit principles.

10-2. **Electrical Terms.** We know that there are many terms which apply specifically to electrical circuit descriptions. However, it is not necessary that we mention every term because many are familiar to all electrical systems repairmen, whether he works with automotive electrical systems, building electrical systems, radio systems, or telephone systems. You have seen the terms that we are listing before, in the resident course study materials.

10-3. *Differential.* The differential feature results because of a difference in quantities or quality. For instance, a differential relay operates or fails to operate because of the difference in current. Current in both windings prevents the relay from operating because of magnetic opposition. On the other hand, current in only one winding causes the relay to operate.

10-4. *Energized.* Energized refers to a condition in which current is flowing in the device; thus, it is operating. This statement may not hold true in all circumstances, because some descriptions specify *energized* as the condition in which the device has preoperational current; then an additional surge of current follows which operates the device.

10-5. *Preparing a circuit.* You will often find this expression used when the circuit activities of communications equipment are being described. It identifies an action within a circuit which has several open contacts, where one part of the circuit has just been closed. However, the operating circuit is not complete until all remaining open contacts are closed.

10-6. *Ringing.* Signaling is accomplished by using alternating current. But it is the usual pr[illegible] also to connect the ringing lead to a battery sc[illegible], because this connection permits an associated relay to operate to cut off the ringing. A polarized relay or a slow-to-operate relay may do this. In addition, making the ac circuit a low-value current circuit while the dc circuit is developed to have a greater current flow would allow this cutoff operation. You will often see this connecting procedure referred to as super-imposed ringing.

10-7. Additional terms used in the communication field can be found in the glossary.

10-8. **Electrical Symbols.** Symbols which represent the various electronic devices on electrical equipment schematic diagrams often differ. Figure 3 shows symbols with which you should be familiar. Thinking of each symbol as a part of the circuit and understanding its function makes the circuit analysis easier. As a result, you can determine, locate, and repair trouble more rapidly. NOTE: A capacitor for a circuit could be shown with or without a curved line. Similarly, ac generators can be represented in three ways.

10-9. Figure 4 shows the relationship of some devices in a circuit for one communications system. You will learn more about this circuit in Volume 4. On this figure you can see that the negative of the 24 volt battery (B1) is connected to the B terminal of the four relays (A, B, ST, and FL1). In addition, contacts 3 and 4T of relay B appear beside relay FL1. This appearance is not a true representation of their position because they are actually included within the framework of relay B and beside contacts 2 and 1T. It is not good practice to memorize schematic diagrams for circuits because this type illustration can be misleading. Other circuit symbols for figure 4 are comparable to the symbols of figure 3. For example: straight lines for conductors, circles that represent terminals, and conductors that cross without making a connection. Remember, when you place various symbols together in a specific manner, you have an electrical diagram.

11. Electrical Diagrams

11-1. We saw that figure 4 is a schematic diagram. You know that there are many diagrams that can be used to simplify circuit analysis. Consequently, you should not find it difficult to understand the theory and principles of a telephone circuit. Word descriptions are also used with the circuit diagrams to increase your understanding. Diagrams that we will describe are: schematic, wiring, block, and line and contact.

11-2. **Schematic Diagram.** This diagram (see fig. 4) is most often used when explaining the circuit relationships because the circuits are easier to trace. The schematic allows emphasis of the important features of the circuit. Conventional symbols are used, but their position or placement does not necessarily correspond to the location of the actual part within the equipment. Since schematics are not true pictures of an equipment circuit, learn the principles of operation of the devices of the circuit. This includes a knowledge of the current in the circuit, the voltage at the various components, and the power requirements. Effective understanding is made possible by breaking the complex circuits into a number of simple circuits. Frequently, certain small groups of parts form relatively simple units within the complex circuit. For example, a diagram of a complete telephone system can be broken down into a transmitter circuit, a receiver circuit, a ringing circuit, relay circuits, and several other smaller circuits. You should learn to recognize these units and relate them to the others. Each unit should be understood or thought of in terms of its function in the circuit. Also, try to visualize the actual unit position in relation to its position in the schematic.

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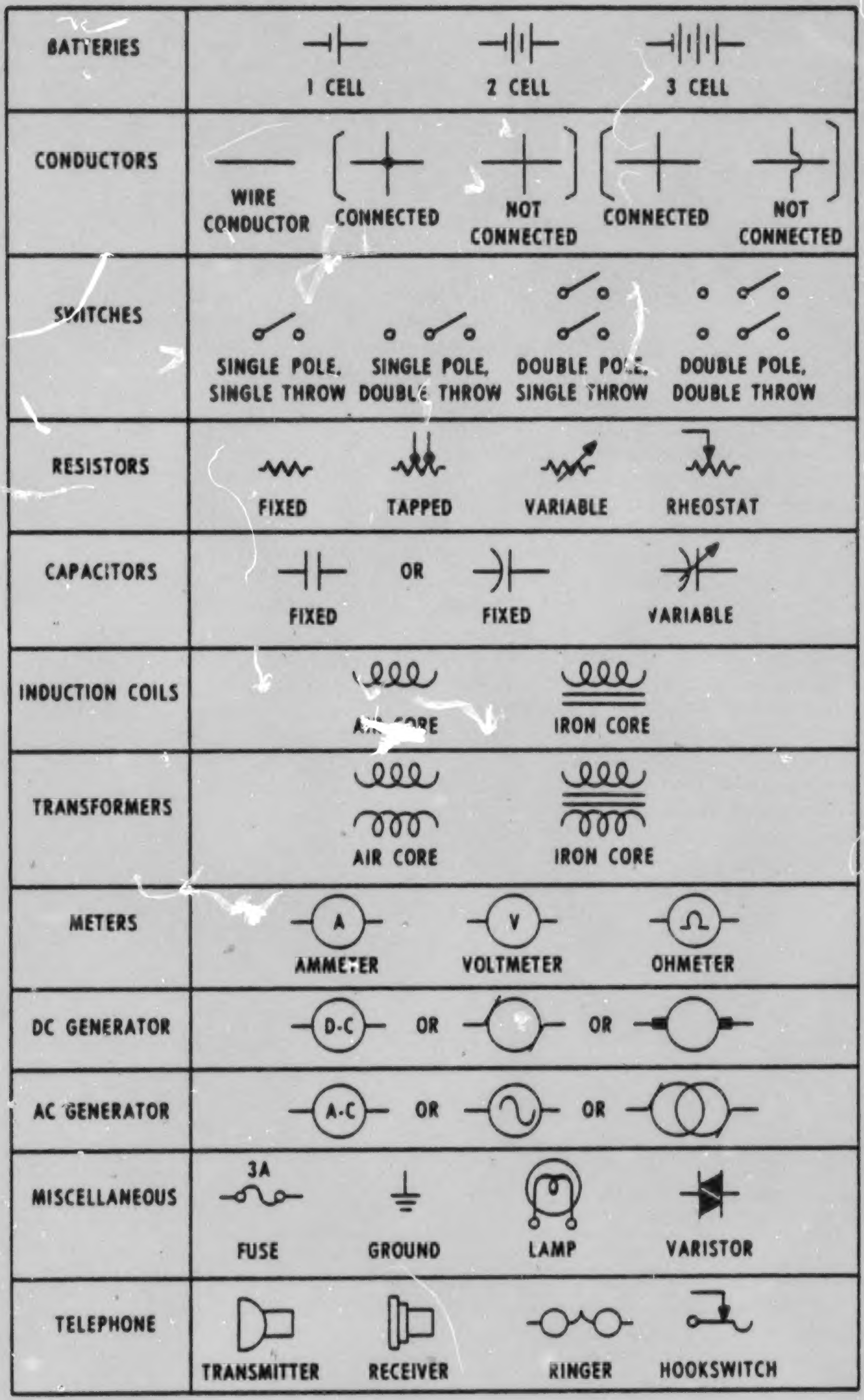
BATTERIES
1 CELL
2 CELL
3 CELL
CONDUCTORS
WIRE CONDUCTOR
CONNECTED
NOT CONNECTED
CONNECTED
NOT CONNECTED
SWITCHES
SINGLE POLE, SINGLE THROW
SINGLE POLE, DOUBLE THROW
DOUBLE POLE, SINGLE THROW
DOUBLE POLE, DOUBLE THROW
RESISTORS
FIXED
TAPPED
VARIABLE
RHEOSTAT
CAPACITORS
FIXED
OR
FIXED
VARIABLE
INDUCTION COILS
AIR CORE
IRON CORE
TRANSFORMERS
AIR CORE
IRON CORE
METERS
A
AMMETER
V
VOLTMETER
Ω
OHMETER
DC GENERATOR
D-C
OR
OR
AC GENERATOR
A-C
OR
OR
MISCELLANEOUS
3A
FUSE
GROUND
LAMP
VARISTOR
TELEPHONE
TRANSMITTER
RECEIVER
RINGER
HOOKSWITCH

Figure 3

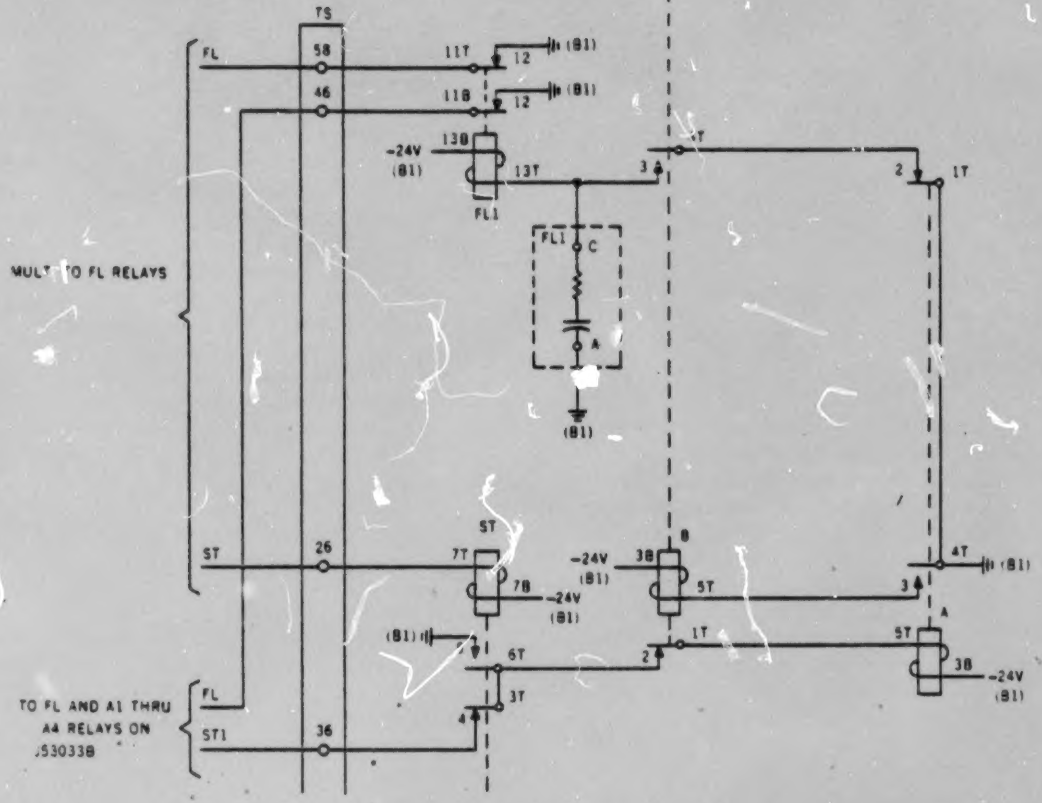
TS
FL
58
46
11T
12
(B1)
11B
12
(B1)
13B
-24V
(B1)
13T
FL1
3
T
2
1T
FL1
C
A
(B1)
MULT TO FL RELAYS
ST
ST
26
7T
7B
-24V
(B1)
-24V
(B1)
3B
B
5T
3
4T
(B1)
(B1)
6T
2
1T
5T
A
3B
-24V
(B1)
3T
4
TO FL AND A1 THRU
A4 RELAYS ON
J53033B
FL
ST1
36

Figure 4

11-3. **Wiring Diagram.** This type diagram illustrates the actual position and connection for each piece of equipment. Because of the emphasis on the connection of cables and terminal wiring, it is not readily used when you are attempting to understand the operation of a circuit.

11-4. **Block Diagram.** The essential units of the system are drawn in the form of blocks, and their relationship to each other is indicated by appropriate connecting lines in a block diagram. The direction or sequence of operation is often indicated by arrows.

11-5. **Line and Contact Diagram.** Often called a drawing, this illustration is a representation of an electrical circuit and its connections through the use of lines and symbols. They usually contain only one simple circuit, which starts at the power source and terminates at a ground, or vice versa. Figure 5 is such a circuit. In it you can see that the power source is represented with a negative 24 V (volt) and a ground symbol. You should remember from your resident training that the × in the line drawing indicates that the device, which it represents, is operated. For example, the B01 above the × in the line drawing of figure 5 identifies an operated relay in the J53033B equipment. Because of this relay operating, contact 12 is operated. As a result, relay A in the J53033M equipment operates. The operating circuit for relay A also includes nonoperated contacts 3 (relay A1), 3T-4 (relay ST) and 1T-2 (relay B). In addition, two terminals (36 & 38) and the ST1 lead are in the circuit.

11-6. Remember that we have illustrated sample circuits of one telephone system. You can use the same or similar methods for analyzing and explaining circuits and operating procedures for any telephone system because all electrical circuits have a voltage, resistance, and current relationship.

12. Voltage, Resistance, and Current Relationship in Electrical Circuits

12-1. We know that electric current is associated with voltage and resistance. These three factors are

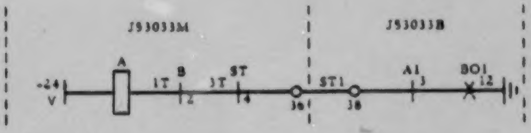
J53033M
J53033B
-24
V
A
1T
B
2
3T
ST
4
36
ST1
38
A1
3
B01
12

Figure 5. Line and contact drawing for a key system circuit.

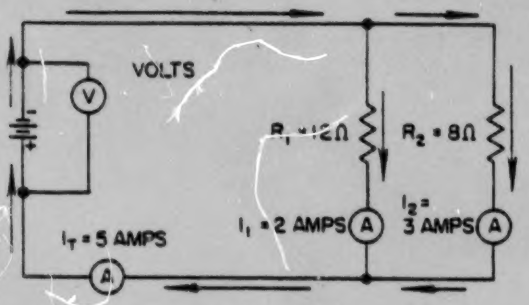
VOLTS
V
R₁ = 12Ω
R₂ = 8Ω
I₁ = 2 AMPS
I₂ = 3 AMPS
I_T = 5 AMPS
A

Figure 6. Sample electrical circuit.

to be found in direct-current, alternating-current, and every other electrical circuit.

12-2. **Direct-Current Circuit Analysis.** Let us look again at figure 4 and assume some resistance values for the purpose of analyzing this circuit. To illustrate, assuming that relay B has 400 ohms resistance, we can determine the current that is required to operate this relay. You should recall that a method used for making this determination is called Ohm's Law. We know that according to this law, the resistance is divided into the voltage ($I = E/R$ or $I = 24/400$). As a result, the total current for our simple circuit is .060 ampere, or 60 milliamperes when contacts 3 and 4T of relay A are made (relay A is operated). Our analysis shows that the operation of relay B also completes the circuit to relay FL1. What, then, would a milliammeter register if placed between contacts 3 and 4T of relay B?

12-3. We immediately recognize that it is impossible to determine the current for relay FL1 while using Ohm's Law because no resistance is shown for it. Again, we could assume a resistance to practice using this law, but it is unnecessary since you used it with relay B, and we will use it again in this chapter. We want you to recall that by placing the milliammeter leads against contacts 3 and 4T, you have placed it in series with the circuit. This is a rule which you should remember. Likewise, you should place the meter controls so that the meter is prepared to read high value current, thus protecting the meter from damage.

12-4. The operated B relay also opens the operating circuit fore relay A. Now, we realize that our previous statement in paragraph 12-2 was not totally correct. Operated relay B moved contacts 3 and 4T together, but the operating circuit for relay FL1 was not really complete yet because contacts 1T and 2 of relay A are open until relay A is released. Consequently, you may consider relays B and FL1 as being parallel operated relays at the moment that relay A is released.

12-5. What are some of the rules that you learned about parallel devices in electrical circuits? The voltage across each device is the same and the current from the power source splits through the branches. This current is determined by the branch resistance and the total voltage. Furthermore, the total resistance in a parallel circuit is less than the smallest branch resistance. Figure 6 will help us review these rules. For instance, the twelve ohm resistor has only two amperes of current, whereas the smaller (8 ohm) resistor has three amperes.

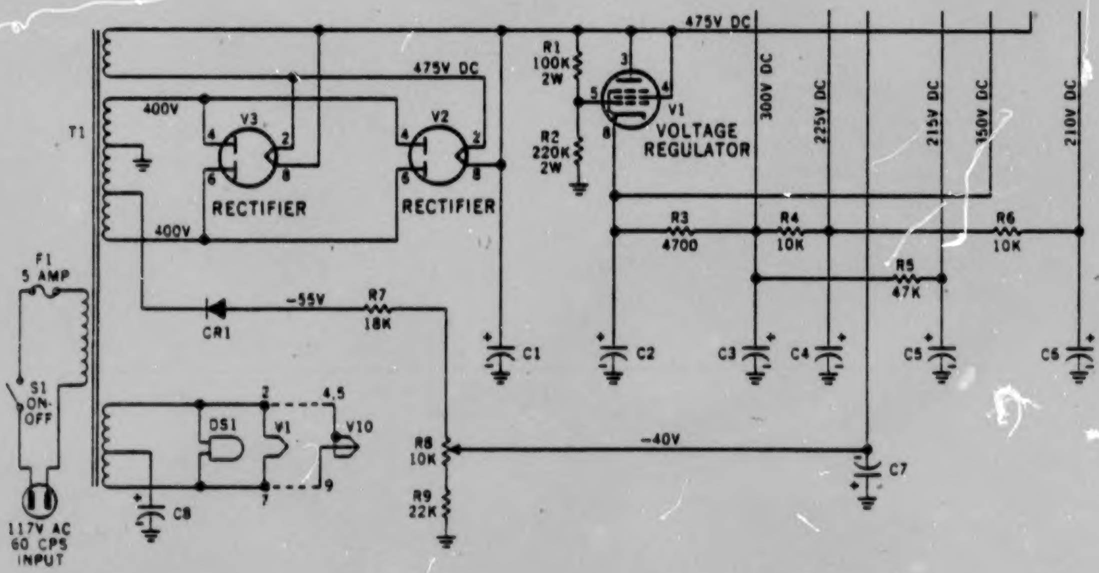
475V DC
T1
400V
V3
RECTIFIER
V2
RECTIFIER
475V DC
400V
R1
100K
2W
R2
220K
2W
V1
VOLTAGE
REGULATOR
300V DC
225V DC
215V DC
150V DC
210V DC
R3
4700
R4
10K
R5
47K
R6
10K
F1
5 AMP
CR1
-55V
R7
18K
C1
C2
C3
C4
C5
C6
S1
ON-OFF
DS1
V1
V10
R8
10K
R9
22K
-40V
C7
C8
117V AC
60 CPS
INPUT

Figure 7. Communications equipment schematic diagram.

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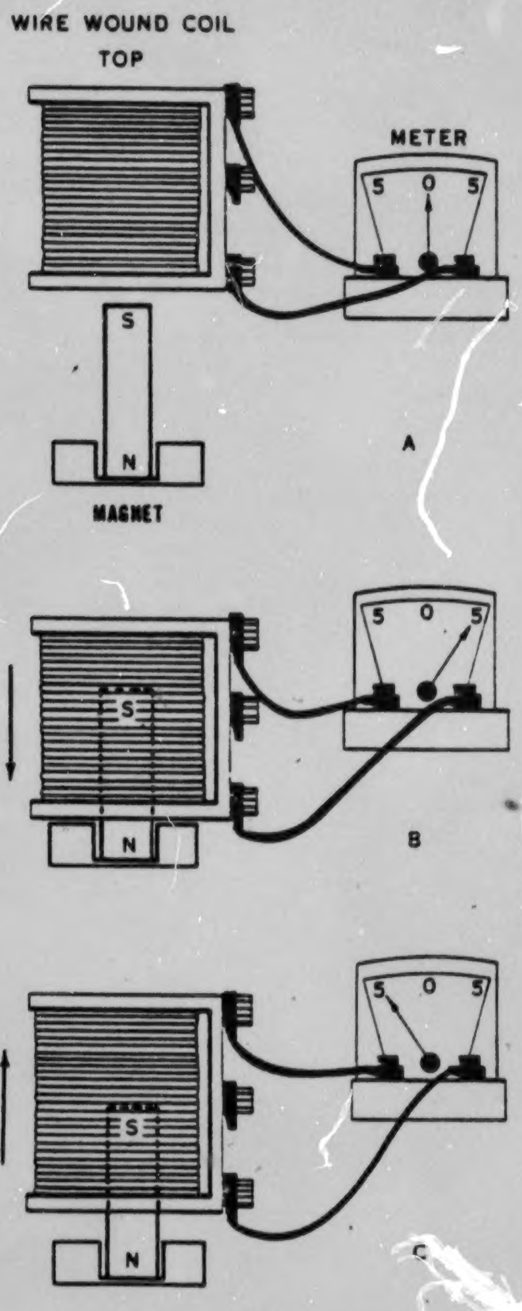

Figure 8. Generation of ac.

Multiplying the current in each branch by its resistance reveals that the voltage for each branch is 24 volts. To determine the total resistance for the circuit, use Ohm's Law (R = E/I). As a result, the circuit resistance is 4.8 ohms.

12-6. We used Ohm's Law for determining current in a dc circuit. E = IR and R = E/I are also applicable. Ohm's Law is useful in ac circuits also.

12-7. **Alternating-Current Circuit Analysis.** Figure 7 illustrates a circuit with 117 volts ac at the input source; yet, the plate circuit for the rectifiers has 400 volts ac. How is this increased voltage possible? The information in the following paragraphs provides the answer to this question.

12-8. We know that many effects result from magnetism. Magnetism enables relays to function. Magnetism as it affects relays is covered with the equipment which uses them. You will find the information in Volume 4. Mutual induction and self-induction are magnetic effects. Although magnetic effects may actually be inseparable, we will view them as individual elements. We will first review the use of a magnet, motion, and conductors to generate alternating current.

12-9. *Generating alternating current.* The demonstration shown in figure 8 is representative of those that you saw in the resident course. It reveals the three factors which are necessary for generating alternating current: a magnetic field, a looped conductor, and motion. You can see that the movement of the coil onto (fig. 8,B) and up from (fig. 8,C) the permanent magnet is reflected by the meter. The meter pointer moves first to the 5 at the right, then to the 5 at the left. This same principle is used in a generator. In the generator, the coil windings rotate through a permanent magnetic field. You learned that the number of lines of magnetic force which are cut per second by the looped conductor determines the strength of the voltage that is induced in the conductor. There are a greater number of magnets and a larger number of conductors in generators than have been shown in figure 8. These additional conductors and magnetic poles result in an increased voltage and frequency for the generator's output over that which is developed in the demonstration. Remember that the same effects result if the magnet is moved and the coil is held immovable.

12-10. The major difference between ac and dc generators is their external connections. An ac generator has brushes and sliprings, whereas a dc generator has brushes and a commutator. Figure 9 pictures two magnetic poles for a generator and the armature which rotates between them. The output voltage developed by this rotating armature is called a sine wave. The peak voltage is produced by conductors at the 90° and 270° positions of rotation. We are seldom concerned with these peak voltages, since the equipment normally operates with the effective value of ac. Each sine wave represents an ac cycle. The number of cycles provided per second results in the ac frequency.

NOTE : A frequency term that has been adopted in the electronic field is the word "hertz." Hertz has

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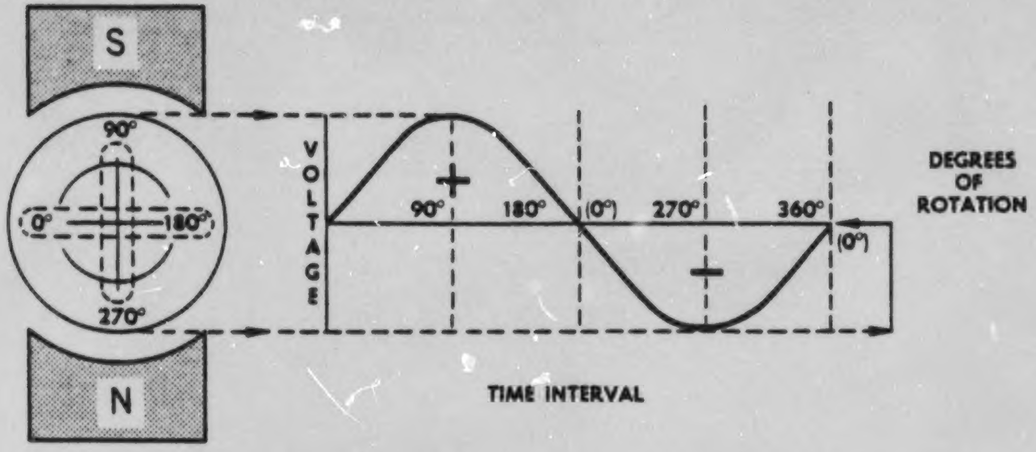

Figure 9. AC sine wave development.

the same meaning as cycles per second and it is abbreviated as hz. By the same token, the term "kilohertz," abbreviated "khz," has the same meaning as kilocycle.

12-11. A moving magnetic field provides the transformer action which increases the voltage in the secondary of T_1 (fig. 7) to 400 volts ac. The magnetic field expands and thus moves through the primary winding and the secondary winding of the transformer. You learned that the magnetic effects on the primary winding is called self-induction. The effects produced by the magnetic field of the primary moving into the secondary are referred to as mutual induction. In both windings, the induced voltage is in opposition to the inducing field's voltage.

12-12. *Self-induction.* The counter or back voltage of a self-inducing device, which has coils or windings, cannot be seen. However, its effects are very noticeable. Look at the coil of figure 10. This coil is shown with 50 ohms opposition. We know that hundreds of feet of wire are required to obtain just a few ohms of opposition; the resistance of wire is determined by the diameter of the wire and the wire type. Wire in the coil of our illustration, then, is not likely to provide the indicated opposition. The self-induction feature of the coil provides the greatest opposition for the circuit. The self-induction opposition of a coil is changed with ac frequency changes.

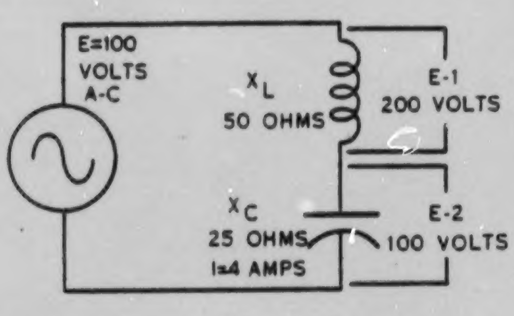

Figure 10. Series ac circuit.

12-13. The opposition shown for the coil in figure 10 would be further increased if it contained an iron core. The iron core allows for a better transfer of magnetic flux between the conductor loops than does an air core coil. This is the reason for the increase in opposition. To illustrate, assume that the coil in our figure has 50 millihenries of inductance and that it is replaced with an iron core coil that has 1 henry of inductance. The opposition to the circuit current should increase to approximately 1000 ohms.

12-14. Let us think about the circuit of figure 10 again. The current in the series circuit is 4 amperes and the opposition offered by the coil is 50 ohms. Using Ohm's law, you learn that the indicated voltage (200 volts) is correct. You should prove the values shown for the capacitor, too.

12-15. What else do you remember about the circuit of figure 10? Is it a resonant circuit? You should recall that the opposition of the inductor (X_L) must equal the opposition of the capacitor (X_C) when a circuit is resonant. This illustrated circuit does not show a resonant condition, since X_L is 50 ohms and X_C is 25 ohms. The frequency must be decreased to bring the two reactances to an equal value, since X_L decreases and X_C increases with this reduction. You also learned that the impedance of a resonant circuit is equal to the resistance, since X_L opposes X_C. In figure 10, the resistance would be slight at resonance because there is no resistor in the circuit. Consequently, with minimum opposition at the resonant frequency, the current is high. This illustrated figure also reveals another characteristic of an ac circuit with a series inductor and capacitor.

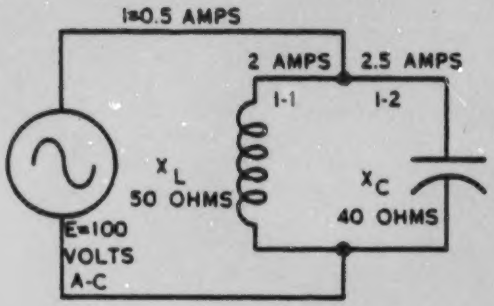

Figure 11. Parallel ac circuit.

The voltage at each reactive device is high when compared to the input voltage.

12-16. A series-resonant circuit is used to filter an undesired frequency from a circuit or, as often stated, "to pass the undesired frequency to ground." It is effective because it appears as a short circuit to the resonant frequency but as high opposition to other frequencies.

12-17. Figure 11 illustrates a parallel arrangement of a capacitor and an induction coil. Since they are in parallel with the source of power, we know that each device has 100 volts applied to it. Thus, you can check the listed circuit values with Ohm's law to verify that they are correct. The total current shown for the circuit of this figure should help you remember that this type of circuit is characterized by having minimum current at resonance. Also, we can conclude that a circuit which has minimum current must have high impedance. The primary need in equipment with this type of circuit is voltage stability for one frequency and good discrimination against the off-resonance frequencies. Indeed, a parallel-resonant circuit is widely used in electronic circuits for restricting frequencies while passing another frequency or for passing a frequency and its band (closely related frequencies).

12-18. *Mutual induction.* We know that this type of induction is accomplished by magnetically linking the primary circuit of a unit to the secondary circuit. Such a linking device has been identified as a transformer, induction coil, or repeating coil. The transformer can provide a greater or lesser voltage from the secondary than is applied to the primary, as well as an output voltage of the same value. Remember: the transformer output voltage is always ac whether the primary input is interrupted dc or ac. The turns (loops) ratio between the primary and secondary determines the voltage relationship. You learned that a transformer which has the most turns in the primary has an output voltage lower than its input voltage. Of course, a transformer can have a combination of step-up and step-down secondaries. Transformer T_1 of figure 7 has three secondaries: two are step-down types and the third is a step-up type. The two short secondaries (filament secondaries) of the figure have less than 117 volts. The step-up secondary provides the rectifier plates with 400 volts ac. You should realize, however, that the power in the secondaries cannot exceed the power of the primary. Thus, the current relationship does not follow the voltage pattern. To illustrate: the current in the rectifier plate secondary will not be greater than that in the filament secondaries.

12-19. Iron cores are also used in devices which operate because of mutual induction. The greater magnetic flux transfer provides for increased efficiency. T_1 of figure 7 contains an iron core, as is symbolized with the two long lines between the primary and secondaries. Because of the magnetic link between primary and secondary, it is logical that any change in one will affect the other. A decrease in the load (opposition) for the secondary can automatically increase current in the secondary and primary. This is a reason for a fuse becoming open in a primary circuit when a resistive device becomes shorted in electrical equipment.

12-20. What is the total opposition of the input circuit for the equipment of figure 7? You know the maximum current and the applied voltage; therefore the total resistance can be determined by using Ohm's law. Hence, you use $R = E/I$. The total resistance is 23.4 ohms.

12-21. Figure 7 shows six dc potentials as output voltages. What component provides the differences in voltage values? The answer to this question is a resistor or several resistors. Resistors are often spoken of as current limiters or voltage limiters. A 10,000-ohm resistor (R_4) provides the 15 volt difference in output voltage at C_4 and C_6. NOTE: This voltage difference will be seen only if there is current in the voltage regulator, which indicates that the circuit is operating.

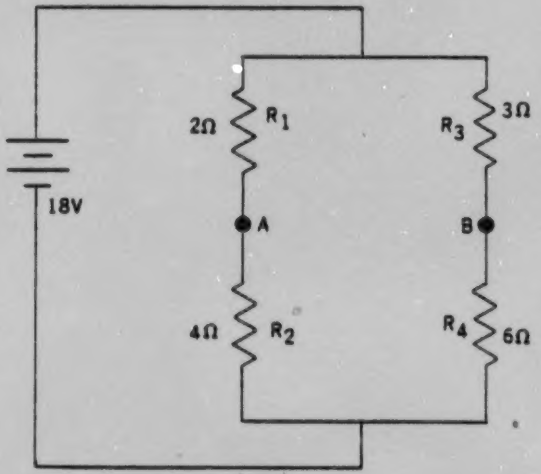

Figure 12. Series-parallel bridge circuit.

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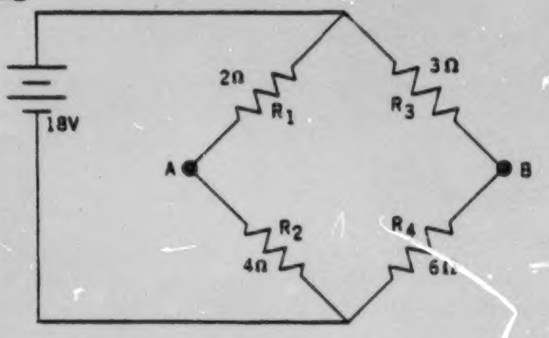

Figure 13. Basic bridge circuit.

12-22. Our discussion of the foregoing paragraphs has shown several things. Briefly, they are:

a. Ohm's Law can be applied to any part of a circuit or to the complete circuit when two factors are known.

b. Voltage at each parallel branch is equal.

c. Resonance is a circuit condition where reactances are equal.

d. Magnetism provides many functions for an electrical circuit.

12-23. Four additional rules are also true. You learned this in your resident course study. They are:

a. Total current is equal to the sum of the currents in parallel branches.

b. Current is the same in each part of a series circuit.

c. Total resistance is the sum of the resistors in a series circuit and the reciprocal of the sum of the reciprocal for the resistors in parallel. The product over the sum method is also useful for determining resistance in a parallel circuit, in some cases.

d. Total voltage is equal to the sum of the drops in each loop of a series-parallel circuit.

12-24. **Resistive Bridge Circuit Analysis.** The bridge circuit is basically a parallel arrangement with a load of some sort connected between its branches. It is used in numerous applications in the communications field, especially in test equipment and power supplies. Bridge circuits may be constructed with either fixed or adjustable components and may contain such items as fixed resistors, variable resistors, diodes, capacitors, or inductors. In addition, the bridge circuit may be regarded as balanced or unbalanced. We will first consider a balanced bridge.

12-25. *Balanced bridge circuit.* In figure 12 you can see a parallel circuit consisting of two branches, each having two series connected resistors. We know that current flows in each branch and the two currents join to return to the battery. Near the center of each branch are two terminals, identified as A and B. Figure 13 is the same circuit as figure 12, but the illustration is drawn to form the characteristic diamond shape of a bridge circuit. For the bridge to be complete, however, there must be a load of some kind connected between terminals A and B. This may be a resistor, coil, or any one of numerous electrical devices. In most test equipment, it is normal for the device in this position to be a galvanometer. The galvanometer shows the current that is flowing when the bridge is unbalanced.

12-26. What makes this bridge circuit balanced? The answer to this question is that a balanced bridge circuit has no potential difference between terminals A and B. A second question is: How do you determine when a bridge circuit is balanced? Two common methods by which this may be done are the ratio relation method and the Ohm's law method. We will first show the ratio relation method.

12-27. In figure 14 the bridge circuit has had arrows added that show the relation between the four resistors. Note that R_2 is twice as large as R_1, and R_4 is twice as large as R_3. Therefore, we can see the relationship that follows:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \text{ or } \frac{2}{4} = \frac{3}{6} = \frac{1}{2}$$

From the above problem, it can be seen that the two branches have an equal ratio. Furthermore, the ratio for resistors R_1 and R_3 is equal to the ratio for resistors R_2 and R_4 ($2/3 = 4/6$). Thus, the circuit is in balance.

12-28. To check the circuit by Ohm's law, we must determine the potential difference, if any, between terminals A and B. To do this, follow four steps:

(1) Determine the resistance of branches A and B.
(2) Determine the current for branches A and B.
(3) Calculate the voltage for terminals A and B.
(4) Find the potential difference between terminals A and B.

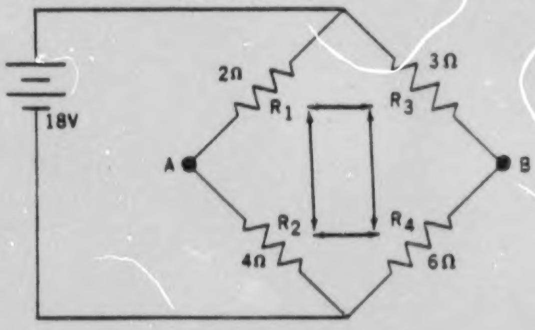

Figure 14. Relation between bridge resistors.

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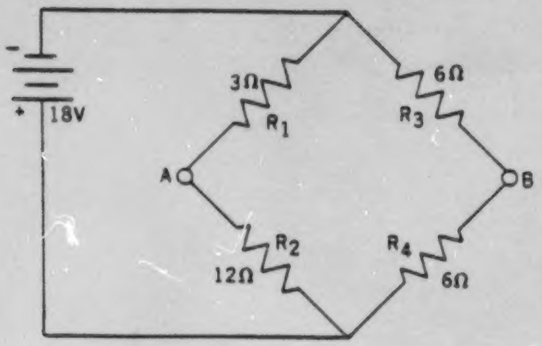

Figure 15. Unbalanced bridge circuit.

12-29. Since the resistors in each branch of our bridge circuit are in series, we can add them to get the total resistance of that branch. To illustrate: 2 ohms plus 4 ohms in the A-terminal branch results in 6 ohms total. The B-terminal branch has 9 ohms. The voltage at each branch is equal to the applied voltage (18V). Now, we have the voltage and resistance; hence, we can solve for the current in each branch. Using I = E/R, we find the current to be 3 amperes in branch A and 2 amperes in branch B.

12-30. Return to figure 13 and picture R_1 as having 3 amperes and R_2 as having 2 amperes. Again, we have two factors for each resistor. Therefore, we can get the voltage at those resistors by using Ohm's law. R_1 has a voltage drop of 6 volts and R_3 has a voltage drop of 6 volts. The same procedures are used to get the voltage at resistors R_2 and R_4.

12-31. Now compare the voltage at terminal A to the voltage at terminal B. Since both terminals are 6 volts negative in respect to positive battery, it is evident that the circuit is balanced. Of course, you can also consider the two terminals 12 volts positive with respect to negative battery. Again, it means that the circuit is balanced because there is no potential difference between terminals A and B. If a galvanometer is placed between terminals A and B, there will be no current flow through the meter.

12-32. *Unbalanced bridge circuit.* The unbalanced bridge circuit has a potential difference between terminals A and B. Therefore, current will flow in a galvanometer that is connected between them. To solve for circuit values in an unbalanced bridge, use the methods described with the balanced bridge. Take the bridge of figure 15 as an illustration. Use the Ohm's law method and follow the four steps listed in paragraph 12-28.

Step 1 (resistance of branches)

$R_1 + R_2$ = 3 ohms + 12 ohms = 15 ohms.
$R_3 + R_4$ = 6 ohms + 6 ohms = 12 ohms.

Step 2 (current through branches)

$I = E/R_A \quad I = \frac{18}{15} = 1.2$ amperes

$I = E/R_B \quad I = \frac{18}{12} = 1.5$ amperes

Step 3 (voltage at points A and B, when compared to negative battery terminal)

E_A = IR E = 1.2 × 3 ohms = 3.6 volts
E_B = IR E = 1.5 amperes × 6 ohms = 9 volts

Step 4 (potential difference between terminals A and B)

$E_B - E_A = 9 - 3.6 = 5.4$ volts

12-33. As you can see from the above calculations, point B in figure 15 is 9 volts positive with respect to the negative battery terminal. Point A is only 3.6 volts positive with respect to the same terminal. Comparing point A to point B, we see that B is 5.4 volts positive with respect to the former. This difference in potential permits current to flow from A to B whenever a load is connected between the two terminals. Of course, the current is determined by the size of resistance in the load and the potential difference of the terminals.

12-34. Adding a galvanometer to the circuit changes the total resistance, which in turn changes the current in the branch resistors. As a result, the voltage is likewise changed for these resistors. To illustrate, assume that the resistance through a galvanometer is zero. A conductor with zero ohms placed between terminals A and B results in making

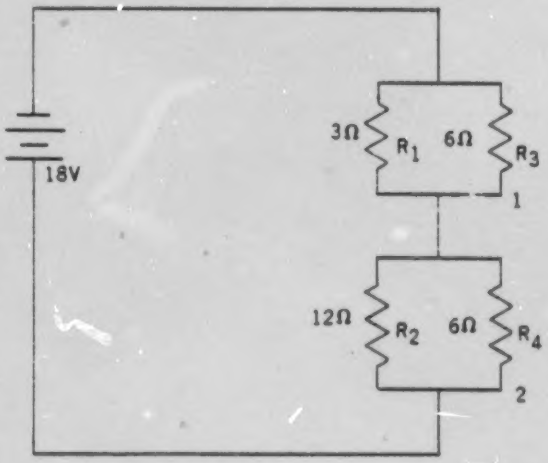

Figure 16. Two parallel circuits in series.

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a new circuit. Compare figures 16 and 15 and note the difference. This short circuit has formed two parallel circuits. Also, the two parallel circuits are in series with the 18-volt power source. The following solutions show the new circuit values.

Step 1 (resistance of branches)

$$\frac{R_1 \times R_3}{R_1 + R_3} = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2 \text{ ohms}$$

$$\frac{R_2 \times R_4}{R_2 + R_4} = \frac{12 \times 6}{12 + 6} = \frac{72}{18} = 4 \text{ ohms}$$

Step 2 (total resistance of branches)

$$B_1 + B_2 = 2 \text{ ohms} + 4 \text{ ohms} = 6 \text{ ohms}$$

Step 3 (total current)

$$I = E/R \quad I = \frac{18}{6} \quad I = 3 \text{ amperes}$$

Step 4 (voltage at each branch)

$$E = IR$$
$$E = 3 \times 2 \text{ ohms} = 6 \text{ volts (circuit 1)}$$
$$E = 3 \times 4 \text{ ohms} = 12 \text{ volts (circuit 2)}$$

Step 5 (current in each resistor)

$$I = E/R$$
$$I = \frac{6}{3} = 2 \text{ amperes } (R_1)$$
$$I = \frac{6}{6} = 1 \text{ ampere } (R_3)$$
$$I = \frac{12}{12} = 1 \text{ ampere } (R_2)$$
$$I = \frac{12}{6} = 2 \text{ amperes } (R_4)$$

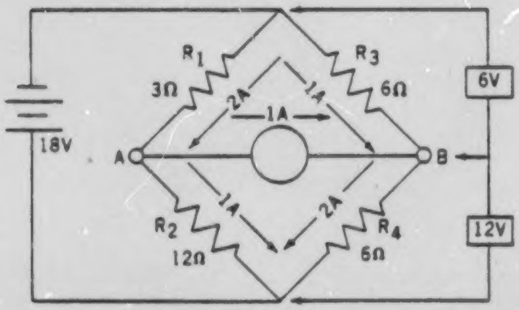


Figure 17. Galvanometer connected across bridge circuit.

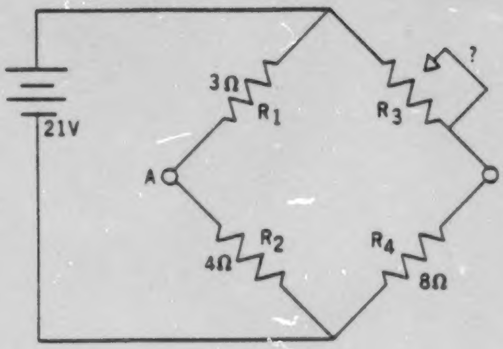


Figure 18. Bridge circuit with variable resistor.

12-35. These new values, with a galvanometer between the terminals, are illustrated in figure 17. From this illustration, note that 2 amperes flow through R_1; yet only 1 ampere is shown for resistor R_2. In the same manner, resistor R_4 has 2 amperes while R_3 has only 1 ampere. It is evident, then, that 1 ampere must flow through the galvanometer (from point A to point B).

12-36. The solutions and description of the preceding paragraphs reveal that loading a bridge circuit with a galvanometer changes the current and voltage from that to be noted when the circuit is not loaded. This effect is true whether the load is low or high resistance.

12-37. In paragraph 12-24 we mentioned that bridge circuits could contain variable components. Figure 18 shows a bridge circuit that contains a variable resistor. This resistor is used to balance an unbalanced bridge. When current is noted in the galvanometer of the bridge circuit, the control of the variable resistor is rotated until the current ceases in the galvanometer. Look again at figure 18 and determine the resistance required for R_3 when balancing the bridge. NOTE: The slider reduces the resistance by short-circuiting resistance windings. The answer to this problem can be solved by the ratio method. By substituting X for the unknown resistance, we can solve the problem by using the ratio formula:

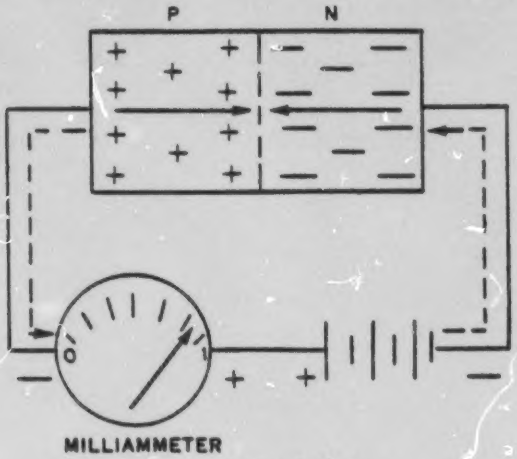
$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

thus

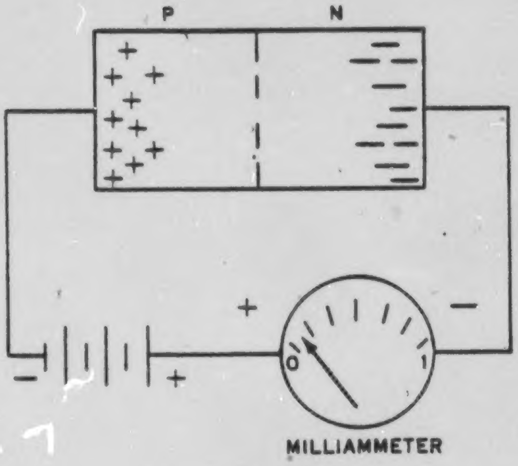
$$\frac{3 \text{ ohms}}{4 \text{ ohms}} = \frac{X}{8 \text{ ohms}}$$

Therefore

$$4X = 3 \text{ ohms times } 8 \text{ ohms}$$
$$4X = 24 \text{ ohms}$$
$$X = 6 \text{ ohms } (R_3)$$



A. FORWARD BIAS



B. REVERSE BIAS

Figure 19. Biasing of solid state devices.

We can now see that R_3 must be adjusted to 6 ohms to balance the bridge. Any other resistance, above or below 6 ohms, causes a potential difference between terminals A and B. This potential difference is indicative of an unbalanced bridge.

12-38. **Solid State Circuit Analysis.** Current has been described in wires, resistors, coils, etc. You learned in the resident course that the N-type semiconductor also operates because of electron movement. The P-type semiconductor is useful because current is produced by moving holes. You also learned that the electron has a negative charge, whereas the hole has a positive charge. The two types of semiconductor materials have been joined to form solid state diodes and transistors.

12-39. Combining a P-type semiconductor with an N-type semiconductor will not result in a current flow until an external energy source is connected to the fused units. Each device has a low-resistance direction and a high-resistance (reverse) direction. Once the required potential is applied to the device in the direction of the low resistance, current flows through a minimum of opposition.

12-40. *Simple diode circuit.* We know that "forward bias" is the application of voltage to a solid state device in a manner which permits current to flow in the forward direction. Figure 19,A, shows a solid state device which has forward bias. As a result, the milliammeter in the external circuit registers nearly a full-scale meter deflection. Reversing the connections of the battery would cause a reduction in the current—because of the electrons in the N-type material would be attracted toward positive battery, and at the same time the positively charged holes of the material would have a great attraction for negative battery. As a result, the space charge area becomes broadened, and there are fewer electrons and holes to combine. Figure 19,B, shows the effects of "reverse bias" on a PN-type solid state diode.

12-41. We realize, too, that a junction device is comparable to a rectifier; current flows readily in one direction and is restricted in the reverse direction. We know, too, that a device which provides one-direction (unidirectional) current flow is also referred to as a diode. The symbol of figure 20 is used with rectifiers. The emitter and collector nomenclature on the symbol designate the rectifier as a junction diode.

12-42. Applying reverse bias to a junction diode has proved to be of value in electronic circuits, although this condition is used to a lesser extent than is the application of forward bias. When the reverse bias voltage is sufficient to breakdown the crystal and allow varying amounts of current to flow, the junction diode performs as a voltage regulator. For this regulation to be possible, a proper load resistor must be placed in series with the diode. Figure 21 should enable you to recall the principle of voltage regulation while using a Zener diode. While looking at this circuit, assume that the input voltage has increased. This greater voltage is applied to series resistor R_1 and Zener diode CR_1. This voltage increase causes the diode to conduct more current. Nevertheless, the increase in current does not result in a voltage change at the terminals of the diode. Since the load is parallel to the diode, it likewise has

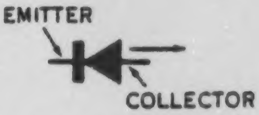


Figure 20. Rectifier symbols.

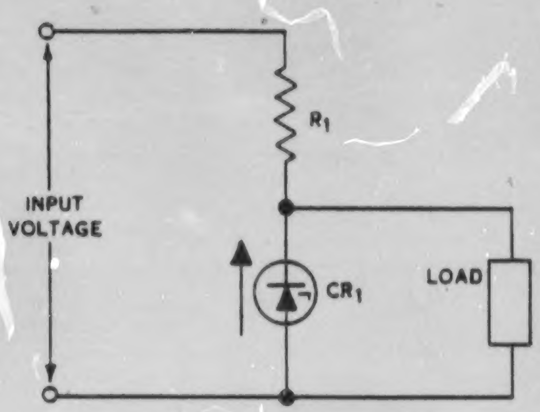


Figure 21. Zener diode as a voltage regulator.

no change in voltage. Changes in current or voltage in the power source or in the load are compensated for by the Zener diode. In transistorized equipment you may see Zener diodes used as voltage regulators because they are small, have excellent regulation characteristics, and require a minimum of power.

12-43. Silicon diodes are being used as rectifiers in many electronic power supplies. Their small size, light weight, reliability, lack of a need for filament heat, and high voltage ratings are reasons for their use. They can be used with half-wave, full-wave (bridge type), or center-tapped transformer rectifier circuits.

12-44. Transistors can provide most of the functions required of electronic equipment. While providing the function, the transistor does not deteriorate, requires a minimum of power, takes less space than most electronic devices, is shock resistant, and has a very high operating efficiency. Included as its functions are amplification and switching, at either low or high speed.

12-45. *Simple transistor analysis.* A transistor is also useful in electronic circuits. This device consists of two units of one type semiconductor material and of a unit of the second type. Current flow in the transistor is the result of a bias. Likewise, its bias can be either forward or reverse. You also learned that an oscillating potential is provided, in addition to the battery potentials of the transistor circuits. Consequently, the voltage for the transistor will be alternately slightly higher than or slightly lower than the bias set by the battery. To illustrate: if the voltage of the bias battery is 6 volts and the oscillating (generator) potential is 0.5 volt, the control voltage will vary from 6.5 to 5.5 volts.

12-46. Because of amplification, many functions are possible. Each function is often identified individually because its effects result in observable signal differences. Since each function is commonly thought to be used separately, we will describe each one individually.

12-47. *Amplifier circuits.* You have learned that voltage, current, or power can be increased (amplified). The input signal to a transistor can be amplified as high as 1000 times by the transistor (stage). Amplification is described as the difference between the input and output signals. For example, assume that the signal for the generator in figure 22 is 0.5 volt. Assume, too, that the voltage at the collector connection (or load resistor) varies from 60 to 55 volts. Thus, the output change is 5 volts. The signal has been amplified 10 times by this transistor. The connections which make transistor amplification possible are not always the same because we want a variety of results. For this reason, transistor amplifiers are classified as follows:

(1) Common-base amplifer.
(2) Common-emitter amplifier.
(3) Common-collector amplifier.

12-48. Common-base amplifiers are also referred to as grounded base amplifiers. The circuit illustrated in figure 22 is a common-base amplifier circuit. This type of circuit has very low current amplification and a moderate voltage and power gain. Consequently, it is not the most valuable amplification device. Figure 22 reveals that the input signal is applied to the emitter and that the output signal is reflected by the load resistor. If an NPN transistor had been used rather than the PNP transistor, the batteries would have been reversed, but the voltage phase relationship would remain the same. In other words, any positive change at the emitter causes an increase in voltage across the load resistor. With the preceding changes, a signal reading at the collector would temporarily be more positive. Vice versa, a negative signal at the emitter results in a more negative signal at the collector output terminal.

12-49. Common-emitter amplifiers provide high voltage and power gain; thus, they are used almost exclusively in amplifier circuits. In addition, they

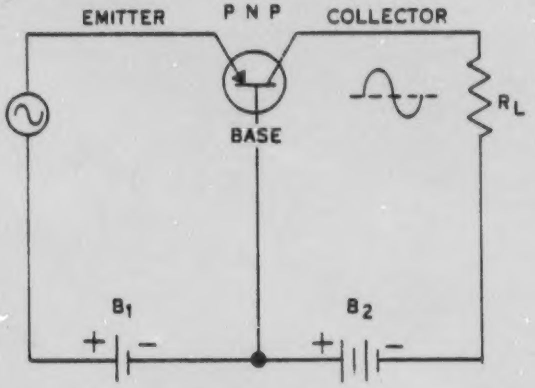


Figure 22. Common-base amplifier schematic diagram.

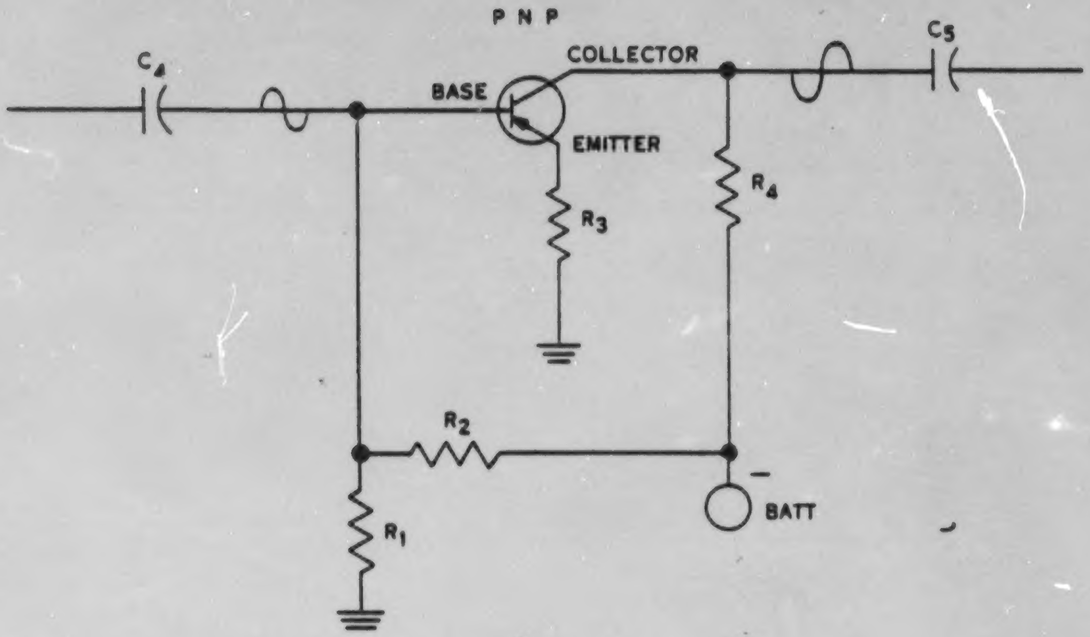


Figure 23. Common-emitter amplifier schematic diagram.

yield a moderate current gain. Figure 23 shows an amplifier stage which has the emitter connected to a grounded resistor. The base is receiving a signal from a coupling capacitor. You can see that this type amplifier has a phase reversal between the base and the collector. Note, then, that the operating characteristic of this amplifier is opposite to the characteristic which you saw in the common-base amplifier. In this circuit, the positive incoming signal opposes the bias voltage. This effect is contrary to the performance noted in the common-base amplifier. The negative signal at the common-emitter is also opposite in effect to the negative signal at the common-base amplifier. Remember: each small change to the bias voltage results in a large change at the output of the amplifier stage. For

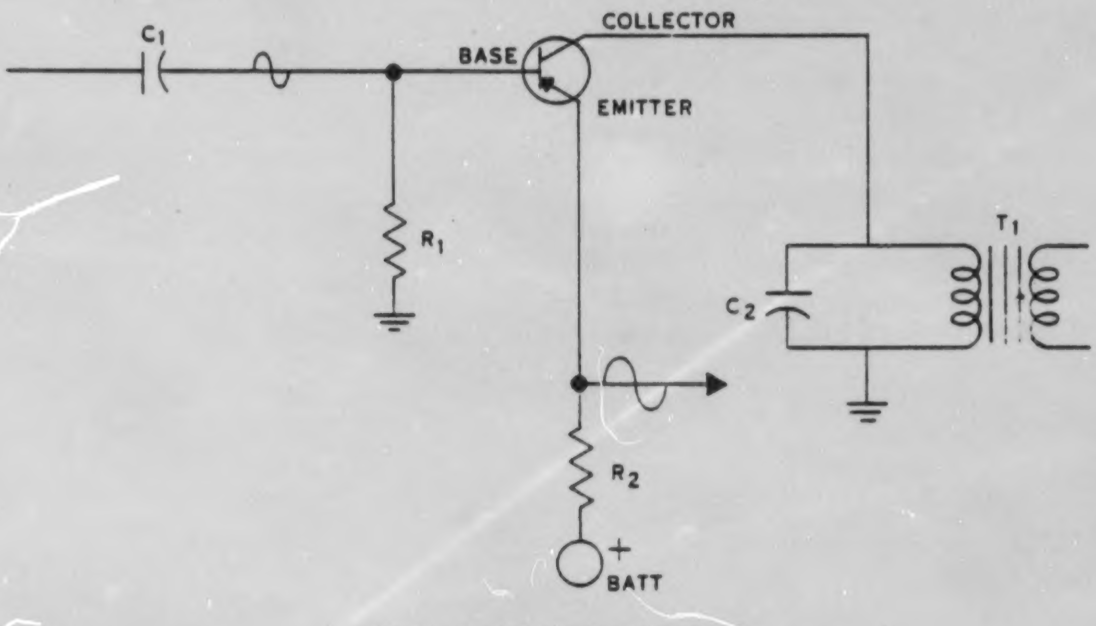


Figure 24. Common-collector amplifier circuit.

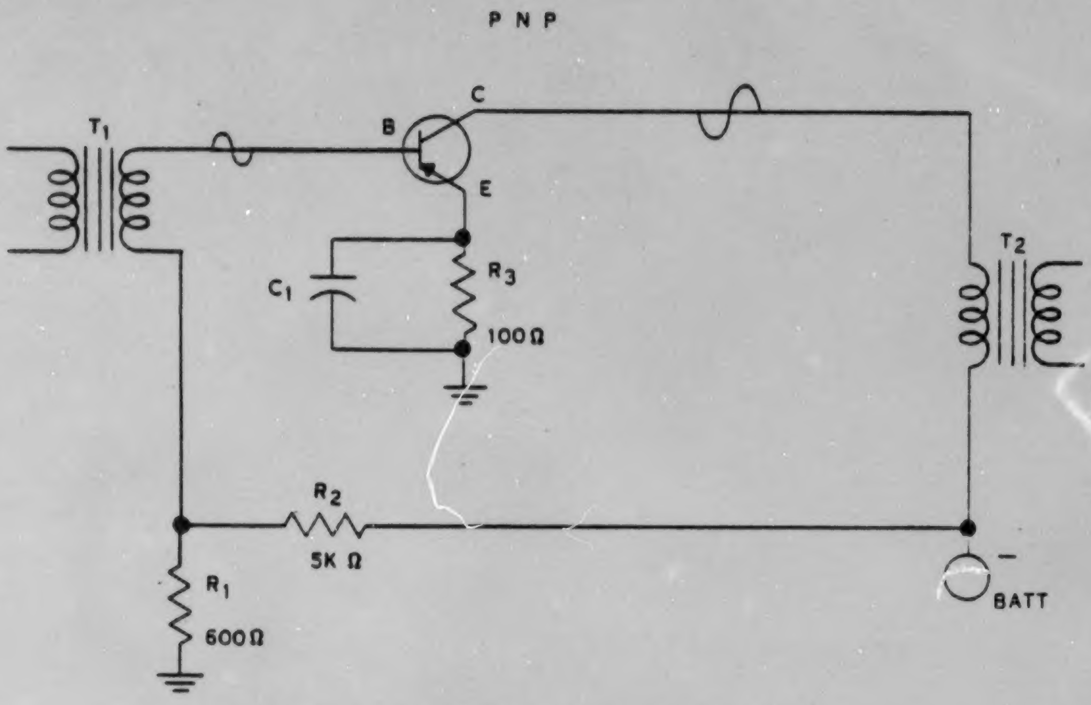


Figure 25. Schematic diagram of a class A amplifier using transistor.

example, 1 volt of change at the input can result in a 10-milliampere change at the output. Of course, a current change is accompanied by a voltage change. Resistor R_3 stabilizes the amplifier by following the changes in collector current. To illustrate: an increase in collector current causes the voltage at R_3 to increase. The reduction in potential between the base and emitter reduces the bias current, thus keeping the amplifier within its correct operating characteristic.

12-50. Common-collector amplifier characteristics are low voltage and power gain and moderate gain in current. Therefore, this amplifier is used only in special circuits. For instance, it is useful as an impedance matching unit. Figure 24 shows this type circuit. In it the collector is connected to ground and the emitter has a positive potential when compared to the collector. In addition, the input signal from the preceding stage is applied to the base. This amplifier stage compares with the common-base amplifier in that it also has no reversal of phase between the amplifier input and output. It can be seen, too, that the output signal can be taken from the emitter. A negative input signal at the base of the transistor of figure 24 results in an increase in current at resistor R_2. As a result, the voltage drop at the resistor is greater following the signal application than it had been before the use of the negative signal. The increased voltage at the resistor results in a more negative output signal. Accordingly, any base voltage change is followed directly by an emitter voltage change. We can see the basis, then, for referring to the transistor as an emitter-follower amplifier.

12-51. We have said that the common-emitter circuit is the most acceptable transistor amplifier. You know from past experience that the circuit is useful in many ways. For instance, it can be used as a class A amplifier, class B push-pull amplifier, or in several other applications. Let us now consider a representative amplifier circuit and determine some of its effects.

12-52. Figure 25 is a schematic diagram of a class A amplifier stage. Current will be in this transistor continuously. The input signal is furnished through a coupling transformer by another amplifier stage. The preceding amplifier could be a vacuum tube or a transistor. The output signal from our illustrated amplifier is coupled by a transformer to the succeeding device. Bias voltage is provided by series resistors R_1 and R_2. We have seen that R_3 provides stability and keeps the stage operating within its normal linear characteristic. Accordingly, a change in the R_3 resistance will result in a distorted output signal, although the input signal is normal. In the same manner, a change in the resistance of either R_1 or R_2 will affect the bias current, which in turn distorts the output signal. This amplifier stage is not often troubled with heat damage when used as a preamplifier because current is small. If a class A amplifier is used as a power stage, there is a possibility of high temperature from the heavy current flow. You will then see that temperature-compensation components are included in the power output stages. These compensation devices provide a current feedback and produce some signal distortion. One such compensating device is the thermistor, which has a decrease in resistance when the temperature rises.

12-53. Now that we have reviewed the fundamentals of electronics and described some of the effects to be noted in circuits which operate because of these principles, let us devote some time to studying trouble analysis.

13. Principles of Trouble Analysis

13-1. Searching for trouble is part of your job. Of course, in your career field some troubles are brought to your attention by the telephone user. All defects provide at least one trouble symptom. Therefore, a knowledgeable repairman can recognize the need for locating the fault. A knowledgeable technician knows the types of faults and understands the conditions that cause the different faults. Successful troubleshooting results from good procedures, accurate thinking, and practice. Troubleshooting requires you to think logically and use a sequence of basic steps. Study your telephone equipment so that you know the trouble symptoms and where to start looking for troubles when a symptom is noted.

13-2. Having identified a trouble symptom, you then should try to analyze the equipment and isolate the fault to a particular unit or circuit. An analysis, however, seldom determines a specific component within the unit as being open- or short-circuited. Your experiences have shown the meaning of open circuit and short circuit. An *open* circuit has no current because the circuit opposition is infinite. A *shorted* circuit has less than normal resistance and an increased current. If you need further review, their definitions are included in the glossary. You may see an intermittent (disappearing) open or short. This type of trouble is caused by a loose connection or a temporary moisture condition. Visual inspection may be the only method for finding the defect. Permanent troubles are generally found by analysis and testing, since they remain in the equipment.

13-3. We will consider sample trouble symptoms and probable troubles for the circuit of text figure 7. To illustrate, lamp DS1 is not lighted when you look at the panel of the power unit. What fault could cause this lamp to be dark? Yes, an open would cause it because no current is to be found in such a circuit. The open circuit, in this case, is at switch S1. When you operate the switch, you short circuit the switch terminals; hence, the circuit has current and lamp DS1 glows. This was a simple circuit effect to analyze. Most defects result in more complex analysis procedures.

13-4. Assume that you have learned that the power unit is not providing adequate voltage; yet, when looking at the power unit panel, the lamp is lighted. Thinking about the circuit of figure 7, we know that the output voltage is largely provided by the operated tubes. Therefore, tube substitution is a probable solution to your problem.

13-5. Another symptom of trouble for the circuit of figure 7 is a blown fuse. This fuse opens when the circuit has excess current. We saw in paragraph 13-2 that current increases when the circuit is short circuited. Replacement of the fuse without knowing that the short circuit is corrected is not a proper procedure because you could burn out the second fuse. Therefore, you should open switch S1 and inspect the equipment. Look for blackened components, loose wires that are touching neighbor wires or terminals, and devices that have strong, strange odors. For example, a charred resistor R_1 could result from a shorted resistor R_2. Note, too, that tube substitution may remove the cause for blown fuses since a shorted tube filament also increases current. The first increase would be noted in the secondary circuit, but this secondary increase also requires an increase in current in the primary. Thus, the fuse opens to indicate the circuit fault.

13-6. Noise is also a circuit trouble symptom. An open filter capacitor and a shorted coil will cause noise because they reduce filtering for the power circuit. Since capacitor input filters are highly charged at the instant of "switch on," they are often more troublesome in electronic circuits than are coils.

13-7. You would use test equipment to check the resistance of the suspected components. However, you must isolate the parallel components to insure that your test is accurate. To illustrate, look at figure 26 and note the resistors. You should remember that the total resistance for a parallel circuit is less than the lowest resistance branch. Testing the two remaining suspected resistors of this figure, you

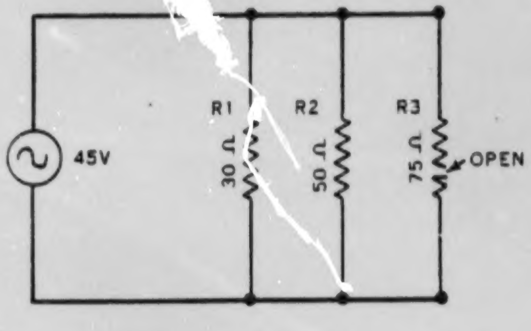


Figure 26. Sample parallel circuit with open branch.

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would find a resistance of 18.75 ohms. Therefore, to determine that R_1 is 30 ohms, you must disconnect it from the circuit.

13-8. Remember: Safety should always be a primary consideration when working with electronic circuits. You can be harmed by transient voltages. The manufacturer installs devices for the high voltages in a specific manner to protect the equipment and the repairman. You need not think about his reason for this arrangement, but you must think about the precautions to take when working with his equipment. For instance, use a test lead and short-circuit the input capacitor to insure that the high voltage is discharged.

13-9. Summarizing, then, a systematic troubleshooter observes the trouble symptom(s), inspects the equipment, analyzes the circuits, isolates the fault to a particular unit, and localizes the trouble by thinking and testing. By following the circuit while using a systematic process of elimination, you can usually locate the fault in a minimum of time. This procedure eliminates the good circuit parts in sequence.

13-10. If you are to fully understand a telephone system, it is necessary that you be familiar with its development and its operating principles. Remember: the better you understand the fundamentals of electricity, the easier it will be for you to complete the following volumes in this course.

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CHAPTER 5

Telephone Fundamentals

TO INSTALL and maintain telephone equipment, you must understand how telephones and telephone systems operate. In the previous chapter, we discussed basic electrical fundamentals and circuits. In this chapter we will explain how these electrical fundamentals are applied in the transmission of sound.

2. By definition, the word "telephony" refers to the use or operation of an apparatus for electrical transmission of sounds between widely separated points. In operation, however, the sound of the speaker's voice is not actually transmitted over long distances, but a sound similar to the voice of the speaker is generated at the distant point by means of electrical power. The sound of the speaker's voice is transformed into electrical power at his telephone, transmitted over wires to any given point, where it is changed into sounds that resemble the voice of the speaker.

3. Since the transmission of voice by telephone begins with sound and ends with sound, it is evident that you, as a telephone man, must have an understanding of sound and its transmission. Furthermore, you must be familiar with the various systems and equipment that are used to transmit the sound in electrical form. To provide you with this information, the material in this chapter is presented under the following sections and headings: sound generation and transmission; sound-powered telephony; local-battery telephony, including basic circuits and components; and common-battery telephone principles.

14. Sound Generation and Transmission

14-1. Sound, as associated with telephony, may be described as being the sensation of hearing. This sensation is caused by stimulation of the nerves and auditory centers of the brain. The stimulation, of course, is caused by vibrations or sound waves which are transmitted to the ear through a material medium, such as air or atmosphere. The sensation of sound is caused by physical vibrations occurring about us in the atmosphere. For example, when someone is speaking to you, the vibrations caused by his vocal cords are recognized by your ears as sound. As another example, the waves established by the vibrating parts of a musical instrument (strings, sounding board, etc.) are recognized by your ears as the sound of music. The medium between the source of vibrations and your ears is the surrounding body of air. The air at atmospheric pressure is sufficiently dense to be set in motion by any vibrating body and to convey the vibrations to the delicate and sensitive membranes in your ears. To further explain the effects of sound, let's briefly consider its generation.

14-2. **Sound Generation.** You learned in the resident course that the motion of air molecules set up by a vibrating body (vocal cords, musical instruments, etc.) produces sound waves which travel

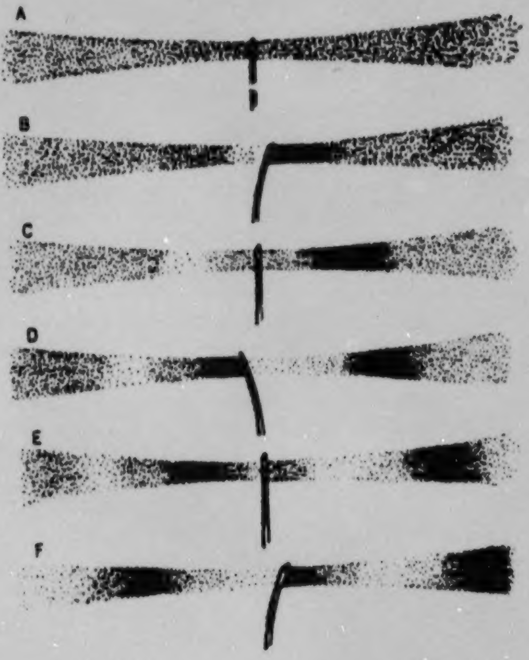

Figure 27. Sound wave produced by vibrating blade.

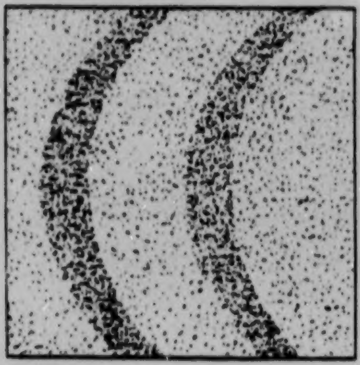

Figure 28. Action of sound waves.

outward in all directions from the vibrating source. The manner in which sound waves are produced can be understood by considering a vibrating strip of metal, such as the hacksaw blade illustrated in figure 27. While looking at this illustration, imagine that the hacksaw blade is fastened to a table in the vertical position and that it is at rest as shown at A in the illustration. Now, if the blade is caused to vibrate rapidly back and forth, two events of opposite nature will occur as the blade makes its initial trip to the right. These two events, as shown at B in the illustration, are: (1) the blade increases the pressure in the group of air particles on its right, causing a bunching-up of the particles on that side; and (2) the blade decreases the pressure in the group of air particles on its left, causing local rarefaction of the particles on that side. This rarefaction on one side and bunching up on the other occur at the same time and are caused by the single motion of the blade to the right.

14-3. While looking at B in figure 27, note that movement of the blade to the right imparts motion to the particles on each side of the blade. As you can see at C in the figure, by the time that the blade has returned to the center, there is a wave of pressure (bunched particles) moving outward on the right side and a wave of low pressure moving outward on the left side. In reference to D, you can see that as the blade moves to the left, a wave of bunched particles is established on the left side and a rarefaction of particles on the right side. As the blade continues to vibrate (see E and F of fig. 27), the waves move outward on both sides of the blade. These waves of both bunches and rarefied particles are the waves that strike the sensitive membranes of the ear, causing the sensation of sound.

14-4. As the sound waves continued outward from their source, the air particles that transmit the energy do not go along with them. Rather, they collide with their outside neighbors, impart their energy, and return to a point close to their original position. The outside neighbors then react in a similar manner by relaying the energy to their outer neighbors, and so on until the energy is all dissipated at some distance from the source. Science compares this effect of sound in the atmosphere with the rings formed in still water when a stone strikes the water's surface. The stone causes a disturbance in the water and creates a series of waves. Similarly, a gunshot creates a disturbance in the atmosphere. It also creates waves through the process of rarefaction and bunching of atmospheric particles. These waves, as mentioned before, are sensed by our ears as sound. The time required for the sound to reach us, however, shows how slowly sound travels in the air. For example, the sound of a distant gunshot or explosion may be heard several seconds after they are observed.

14-5. To further examine the characteristics of sound waves, refer to figure 28. This illustration shows both the wave front, where the air particles are compressed, and the rarefaction, where the particles are relatively further apart. These sound waves may be shown graphically in much the same manner as showing alternating current with a sine wave. As a matter of fact, when a group of sound waves are of identical shape and amplitude, they may be represented by a pure sine wave. If the waveshape is regular in form, the sound we hear may be a steady tone; if the shape is irregular, we may only hear a noise. As an example of graphic representation, look at figure 29, where the sound wave is plotted as a line, and the condensations (points of bunching) are shown by wave peaks. The difference in waveform for each sound allows us to distinguish one sound from another. For instance, a tuning fork, vibrating slowly, establishes a tone of low pitch, whereas a rapidly vibrating fork (causing the waves to be closer together) establishes a tone of high pitch. In addition to this, we may see something vibrate without hearing any sound, because the human ear does not distinguish many sounds below 16 to 20 vibrations per second. Furthermore, the ear parts do not allow us to hear sounds where the number of vibrations is much greater than 20,000 per second.

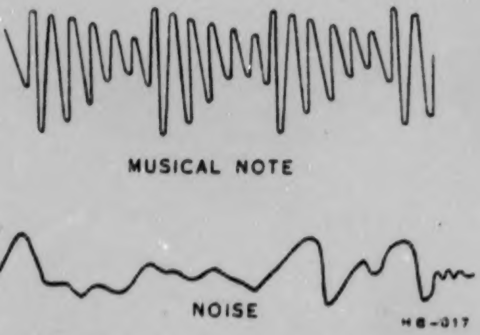

Figure 29. Sound waves of music and noise.

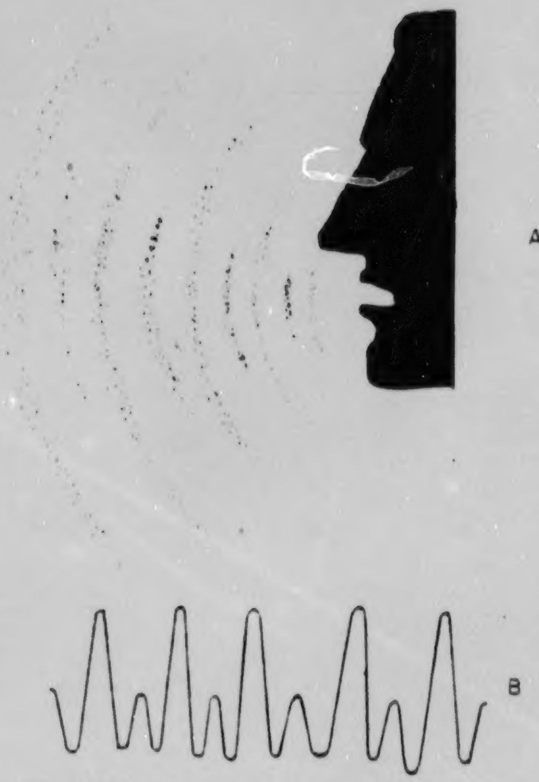

Figure 30. Concept of atmospheric appearance of "oo" sound.

14-6. Sound characteristics provided the clue for the development of the modern telephone. Because Alexander Graham Bell understood both the function of the human ear and characteristics of sound waves, he visualized an instrument which could be operated by the sound of the human voice. His knowledge of electricity indicated that electrical waves were similar to sound waves, and he thought he could shape an electrical waveform to match that of the sound wave and thus transmit sound electrically.

14-7. **Sound Transmission.** Before we discuss the transmission of sound by electrical means, let's consider an important difference between the transmission of sound and the transmission of electrical waves. The transmission of sound always requires a medium. The transmission of light and electricity does not. Thus, sound cannot be transmitted in a vacuum, but light and electricity can. In the direct transmission of sound, the medium is usually the air intervening between the source and the listener; but other mediums, either solid or liquid, can transmit sound. For instance, a boy lays his ear against a railroad track to detect an oncoming train that is too far away for its sound to reach him through air. Also, the American Indian is reputed to have been able to detect faraway [illegible] by pressing his ear to the ground. In both of these cases, the denser medium carried a given amount of sound farther than the sound traveled in air. This principle is also used in the underwater detection of ships. Sensitive listening devices attached to the hull of a ship pick up the sound of propeller vibrations carried by the sea from other ships in the vicinity, particularly from submarines.

14-8. Now, let's discuss the transmission of sound as accomplished by electrical means. As a result of Bell's work, the telephone became an instrument for converting waves of sound into waves of electricity, and waves of electricity into waves of sound. As stated previously, sound is a vibrating disturbance among the molecules of a substance. For example, the sound of "oo" in "loose" produces a disturbance in the air similar to that illustrated in figure 30,A. Note that the successive condensations and rarefactions match the waveform shown in figure 30,B.

14-9. By present standards, Alexander Graham Bell's telephone was a receiver that consisted of a thin reed of magnetic material attached to a small drumhead. Mounted above this reed was a coil of wire wrapped around a soft iron core. Figure 31 shows both the Bell telephone and an early bar magnet receiver. Note that with either of these instruments, a coil located within the field of a permanent magnet has leads or terminals for connection to a line circuit. Both the telephone and receiver have a diaphragm that can be moved by sound waves, and each diaphragm is arranged so

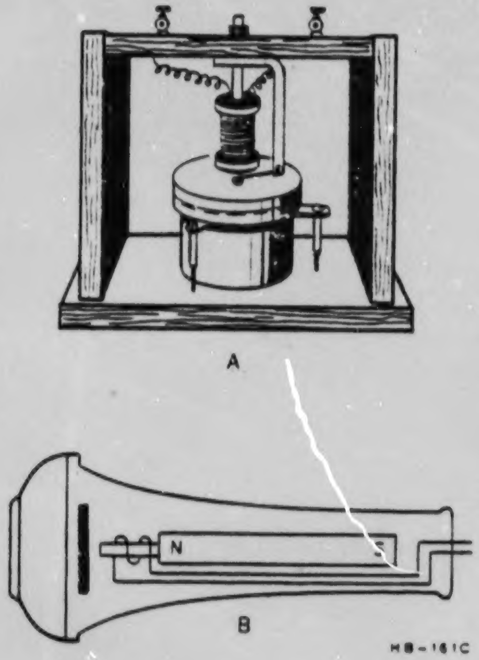

Figure 31. Early telephone and receiver.

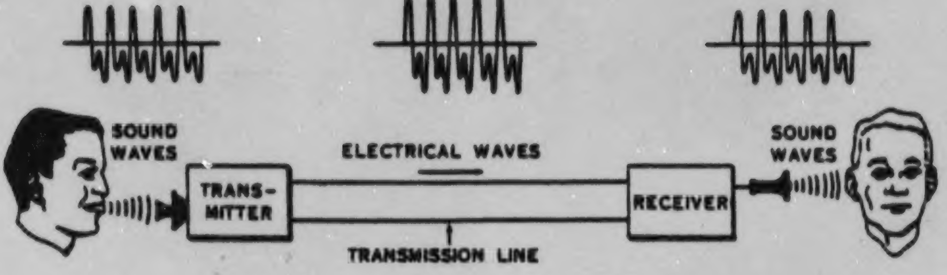

Figure 32. Telephone system function.

that its movement will affect the field of the permanent magnet. With such an arrangement, any movement of the diaphragm by sound waves causes the magnetic field to induce a voltage in the coil. This voltage is of the same waveform as the sound waves that caused it. Also, if the coils of these two units are connected together by a line circuit, the voltage induced in one coil by sound waves will cause the diaphragm in the other unit to vibrate. The vibration of the diaphragm in this latter unit produces sound waves that closely resemble those striking the diaphragm of the first unit. Thus, sound is transmitted from one place to another in the form of electrical energy.

14-10. To further clarify the transmission of sound by telephony, look at figure 32. In this illustration, the man on the left is speaking into the transmitter of a telephone. The sound waves leaving his mouth strike the diaphragm in the transmitter, causing it to vibrate. The vibration of the diaphragm induces electrical waves in the transmission line. As the electrical waves enter the receiver, they vary the strength of the magnetic field, causing the diaphragm in the receiver to vibrate at the same rate as the diaphragm in the transmitter. Thus, the words spoken into the transmitter are reproduced by the receiver diaphragm as sound waves.

14-11. The fundamental principle of telephony may be summarized by the explanation that the sound waves of speech are first converted into electrical waves by the telephone transmitter; secondly, they are transmitted over the wires in electrical form; and thirdly, the receiver converts the electrical waves back into sound waves which, again, correspond in waveform and frequency to the original waves. The listener, in his receiver, thus hears words corresponding to those spoken into the distant transmitter. Various types of telephone systems are in use, but this underlying principle is common to them all. To explain the various types of telephone systems, we will next consider sound-powered telephony.

15. Sound-Powered Telephony

15-1. From the standpoint of how they are powered, the telephone components and systems used in the Air Force are of two general categories: sound-powered and battery-powered. As the names imply, the sound-powered components develop their power from sound, while the battery-powered components use batteries. The largest percentage of all telephone systems and components, used either commercially or by the Air Force, are of the battery-powered variety. The sound-powered components are normally found at special installations, such as missile sites and missile support bases. Since sound-powered components are used to some extent, however, you should be familiar with their operating principles. To explain these principles, let's start with the sound-powered transmitter.

15-2. **Sound-Powered Transmitter.** The transmitter on a telephone set is the part into which you speak when engaged in a telephone conversation. Since the sound-powered transmitter is sometimes used with audio amplifiers, radio transmitters, etc., it is also referred to as a dynamic microphone. However, for our purpose in telephone work, we will refer to the sound-powered unit as a transmitter.

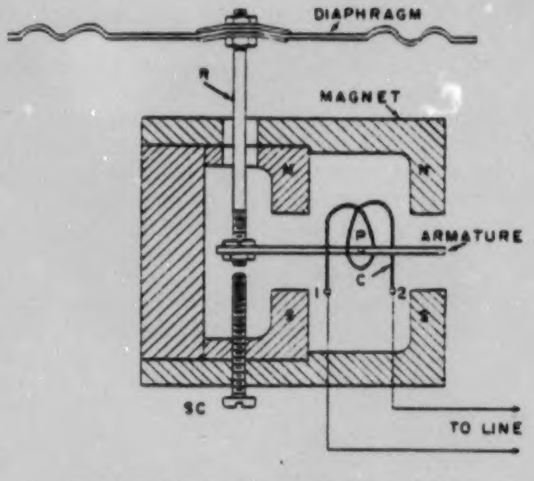

Figure 33. Sound-power transmitter construction.

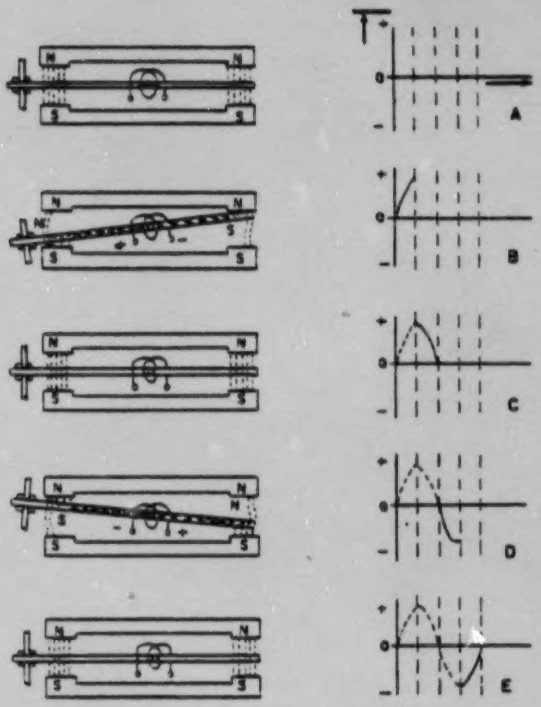

Figure 34. Sound-power transmitter function.

15-3. Figure 33 is a simplified diagram of a sound-powered transmitter. As shown in this illustration, the transmitter has a permanent magnet with double-pole pieces. These magnetic pole pieces are shown with the letters N-N and S-S representing the north and south poles respectively. Notice that a soft-iron armature with a coil labeled "C" is mounted at a point halfway between the pole pieces. This armature is mounted on a pivot at point P, and one of its ends is connected to a diaphragm by rod R. This permits motion of the diaphragm to be transferred to the armature. As the diaphragm is moved downward by sound waves, the armature rotates slightly counterclockwise; and, as the diaphragm moves upward, the armature rotates slightly clockwise. Thus, a voltage is induced in winding C that is similar in waveform to the sound waves striking the diaphragm.

15-4. To study the operation of a sound-powered transmitter, refer to figure 34. Assume that the transmitter diaphragm is moving up and down at a rate corresponding to the sound wave of a steady tone. The armature follows the diaphragm movement (as shown in fig. 34), and the strength of the magnetic field varies in proportion to each movement. When the armature moves away from the center, the strength of the magnetic field within the armature increases (fig. 34,B); consequently, when position B is reached, the strength of the field is at a maximum. Then as the armature returns to position C, the field decreases in strength, because there are, theoretically, no magnetic lines of force through the armature at this center position. Next, the armature field builds up again as the armature ends approach the poles of the permanent magnets. The buildup of this magnetic strength, shown in part D of figure 34, is in the opposite direction to that shown in part B. The return movement of the diaphragm completes the cycle, as shown at E in figure 34.

15-5. You can see that the magnetic field of force within the armature of a sound-powered transmitter varies in strength with the diaphragm movement. When a sound wave moves the diaphragm, the strength of the magnetic field changes with the shape of the sound wave. Then, of course, the shape of the voltage induced in the transmitter circuit matches the shape of the sound wave striking the diaphragm.

15-6. The function of the modern sound-powered telephone is comparable to that of Bell's original telephone; that is, voltage is induced in the sound-powered transmitter coil because the coil is located in a changing magnetic field. This type of transmitter may be used in modern telephony when it is desirable to use a component that does not require the application of battery voltage. This is quite often the case with some of the headsets used at missile installations. For example, whenever a headset uses a transistor amplifier in its cord circuit, you will usually find that the headset transmitter is of the sound-powered type.

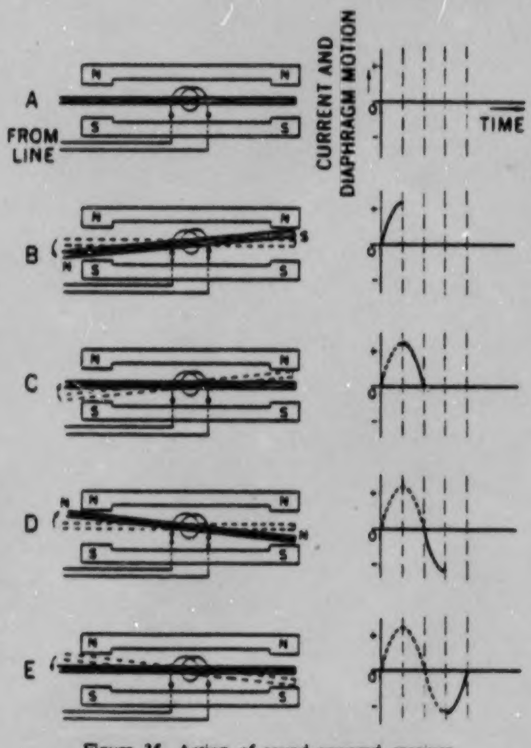

Figure 35. Action of sound-powered receiver.

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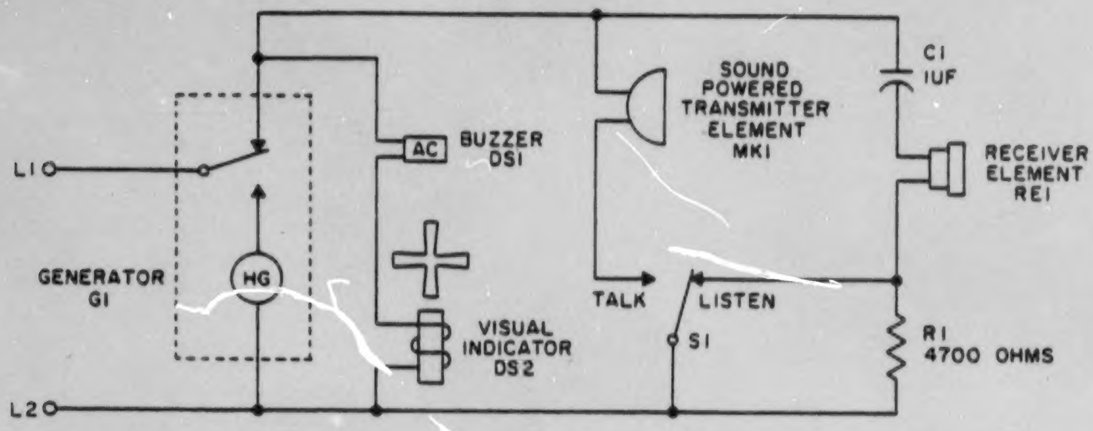


Figure 36. Sound-powered telephone schematic diagram.

15-7. **Sound-Powered Receiver.** In structure, the sound-powered receiver is very similar to the transmitter described in the preceding paragraphs. The principle upon which the sound-powered receiver operates, however, is slightly different from that of the transmitter. When the unit is on the receiving end and receives the electrical waves produced by a sound-powered transmitter, the armature then operates the diaphragm to reproduce the sound waves.

15-8. Figure 35 illustrates the operation of a sound-powered receiver. In part A of the figure, note that the telephone line circuit is connected to the armature coil. In a simple, sound-powered telephone system, the other end of this line circuit would be connected to the armature coil in the transmitter. To follow the operation of the receiver during the application of 1 cycle of alternating current, let's assume that the voltage induced by the sound-powered transmitter (in fig. 34) is applied to the armature coil of the receiver shown in figure 35. When there is no voltage being induced by the transmitter, the receiver armature is at rest as shown at A in figure 35. When a voltage is induced as shown at B in both illustrations, current flows in the armature coil of the receiver, and magnetizes the armature core as indicated by the small letter N and S. This causes the receiver armature to be attracted to the position shown at B in figure 35. When the current falls to zero, as shown at C in the illustration, the receiver armature returns to the center position; and when current flows in the opposite direction, the receiver armature is attracted to the position, as shown at D in the illustration. Finally, as the current falls to zero as shown at E in figure 34, the receiver armature returns to the center (at rest) position.

15-9. To summarize the operation of the sound-powered transmitter and receiver, let's think of the units as being connected together, as shown in figure 32. When sound waves strike the diaphragm of the transmitter, a voltage is induced in the transmitter armature. This voltage causes current to flow in the coil of the receiver armature, causing the receiver diaphragm to reproduce the sound waves. Thus, sound is transmitted from one point to another by sound-powered telephone.

15-10. **Sound-Powered Telephone.** Figure 36 is a schematic for a sound-powered telephone. For this telephone to be operational, it must be connected to another telephone through lines L1 and L2. If you will notice in the illustration, the unit is equipped with a hand generator (HG) that is used to ring or signal the other telephone. Also, it is equipped with a buzzer and visual indicator that function when this unit is signaled from the other station. Furthermore, this telephone is equipped with a generator switch, located just above HG in the illustration, and a PRESS-TO-TALK switch, labeled "S1." To study the operating principles of this telephone, let's trace some of its circuits used during operation.

15-11. *Voice transmission.* When PRESS-TO-TALK switch S1 is pressed, it connects line L2 to the talk contact of the switch to close the transmitting circuit. When you speak into the transmitter, the voice sound waves cause the diaphragm in transmitter element MK1 to vibrate. This actuates the transmitter armature, thereby generating an alternating current of the same frequency as that of the speaker's voice.

15-12. The transmitter current passes through PRESS-TO-TALK switch S1 and then divides; part of the current goes to line terminal L2, while the remainder goes to resistor R_1. Most of the current passes to the line, through the distant telephone, and back to line terminal L1. It then passes through the normally closed contacts of the generator switch and back to the transmitter element.

15-13. A small amount of transmitter alternating current, as limited by resistor R_1, passes through the resistor, receiver element RE1, and capacitor C1, and goes back to the transmitter element. The

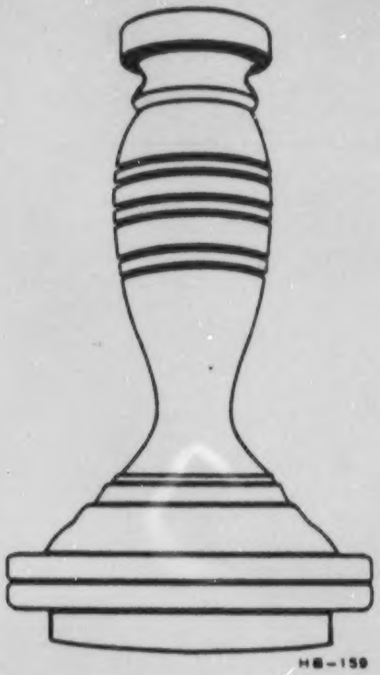


Figure 37. Butter stamp receiver.

purpose of resistor R, is to allow a small amount of transmitter current to pass through the receiver element during voice transmission. This creates a small amount of sidetone so that the telephone will not sound dead during voice transmission. In other words, it allows the user to hear his own voice in the receiver.

15-14. *Voice reception.* The incoming voice signal, tracing from L1, passes through the normally closed contacts of the generator switch, capacitor C1, and receiver element RE1. It then passes through the normally closed contacts of switch S1 (as shown in fig. 36) and goes back to the line through terminal L2.

15-15. As the incoming signal passes through the receiver, it causes the diaphragm to vibrate, reproducing the voice sound of the distant party. The incoming voice current is prevented from passing through the buzzer and visual indicator circuit by the reactance of the windings on the buzzer and visual indicator which offers high impedance to voice frequencies.

15-16. *Signaling.* When the generator switch is operated, it connects L1 to L2 through hand generator HG. When the switch is in this position, operation of the hand generator applies a 20-cps alternating current across lines L1 and L2. This activates the signaling devices in the distant telephone.

15-17. An incoming 20-cps signal from the distant telephone passes from terminal L1 through the generator switch (as shown in fig. 36), buzzer DS1, and visual indicator DS2. From DS2, the circuit is completed back to the generator in the distant telephone via line L2. The passage of 20-cps current through the buzzer and visual indicator causes them to indicate the incoming signal.

16. Local-Battery Telephony

16-1. The early commercial telephone instruments were, in reality, receivers, such as shown in figure 37. These instruments were called *butter stamp receivers* because they resembled the butter stamps used at that time. They were of the sound-powered variety, containing a permanent magnet, a coil of wire, and a sheet iron diaphragm. At that time, two such receivers, connected as shown in figure 38, made up the whole telephone system. These receivers could not operate beyond a distance of approximately 2 miles; hence, they were considerably less efficient than the modern sound-powered sets.

16-2. The circuit used with the early butter stamp receivers further handicapped efficient use. This circuit, as shown in figure 38, was a single wire, with grounds provided at each instrument. The ground return was not very satisfactory, especially when the ground was dry. Also, there was no provision for signaling the called party. Continued efforts were made to overcome these difficulties, until eventually *local battery* systems and a better transmitter were devised. This new unit, called the *solid-back transmitter*, did not generate its own current. Instead, it varied the intensity of a battery current to match the shape of the speech sounds. With this system, a battery was required locally with each telephone; hence, it was named the local battery system. To explain the operation of this type of transmitter we will now briefly discuss sound and electrical waveforms.

16-3. **Waveforms.** Some of the waveforms discussed previously are shown again in figure 39. They are shown in this illustation, however, for comparative purposes. In studying these waveshapes, note that part A of the illustration shows the sine wave of alternating current and the unipolar wave of direct current, which in this form is called constant

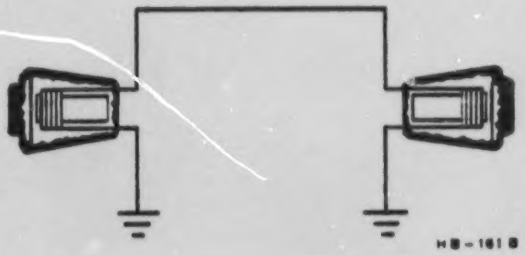


Figure 38. Early telephone system circuit.

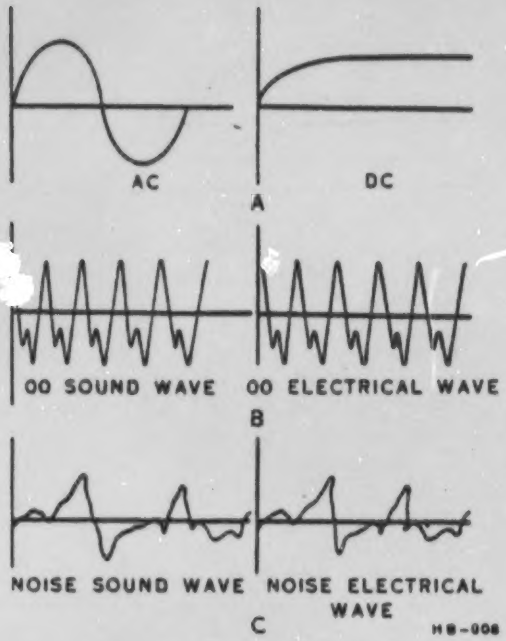


Figure 39. Waveshapes compared.

value dc, constant dc, or pure dc. The waves shown in figure 39, B are the sound wave of the "o͞o" sound and the wave of the electric current from a soundpowered transmitter when it is operated by the sound. In figure 39, C, the irregular sound wave of a noise is shown in comparison with the transmitter current resulting from that noise.

16-4. If the noise wave in figure 39 were combined with the constant dc wave, the result would be like that shown in figure 40. This resulting wave changes in value just as the noise wave did; however, since it is all in one direction, it is still a dc wave. It is called a *variable dc wave;* and like the noise wave shown in figure 39, it changes in value at irregular intervals and has no uniformity.

16-5. Waveshapes can be changed in several ways. If resistance is added to a circuit, less current will flow; if resistance is removed, more current will flow. Although the same circuit is shown in all three diagrams of figure 41, the variable resistor permits different amounts of circuit resistance; thus, the current value drops from A to B and rises from B to C.

16-6. The principle of controlling current by changing resistance is used in modern transmitters. Blake applied it in the transmitter only a year after the first commercial telephone was built. He reasoned that a transmitter should vary the strength of an existing current to match the sound waves that strike its diaphragm. To do this, a transmitter was designed in which the pressure on a container of carbon granules was changed by sound waves striking a diaphragm. Thus, the resistance through the container of carbon granules was varied by the sound waves.

16-7. To become familiar with the waveform produced by the carbon transmitter, compare figure 41 (A, B, and C) with figure 39. The Bell (soundpowered) transmitter generated its own current; therefore, the current wave from that transmitter alternated from positive to negative. On the other hand, the Blake (carbon) transmitter increased or decreased resistance to vary current supplied by a battery. Consequently, the resultant wave was variable dc, as shown in figures 40 and 41. While the wave produced by the carbon transmitter is variable dc, it is still of the same shape as the sound waves striking the diaphragm. Thus, it can be used very effectively in the transmission of sound. As a matter of fact, the majority of telephone transmitters used today are of the carbon type, and they produce a variable dc wave such as illustrated in figure 40.

16-8. Development of Local-Battery Telephone Circuits. With the development of the carbon transmitter, the telephone battery was originally placed on the telephone instrument, as shown in figure 42. Note that each unit in this transmitter-receiver circuit is labeled and indicated by its standard symbol. This local-battery circuit was the granddaddy of the modern telephone. By connecting this telephone through a single line to another identical unit, conversation could be carried on from one point to another. This circuitry, however, did leave much to be desired.

16-9. One of the first improvements made to the local-battery system was to increase the effectiveness of the telephone over greater distances. When the set consisted of a receiver, battery, and transmitter connected in series, there were a number of losses in the circuit. Also, the resistance changes caused by variations in transmitter resistance were so small,

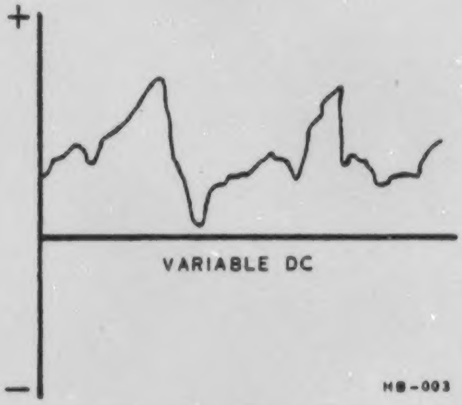


Figure 40. Variable dc waveform.

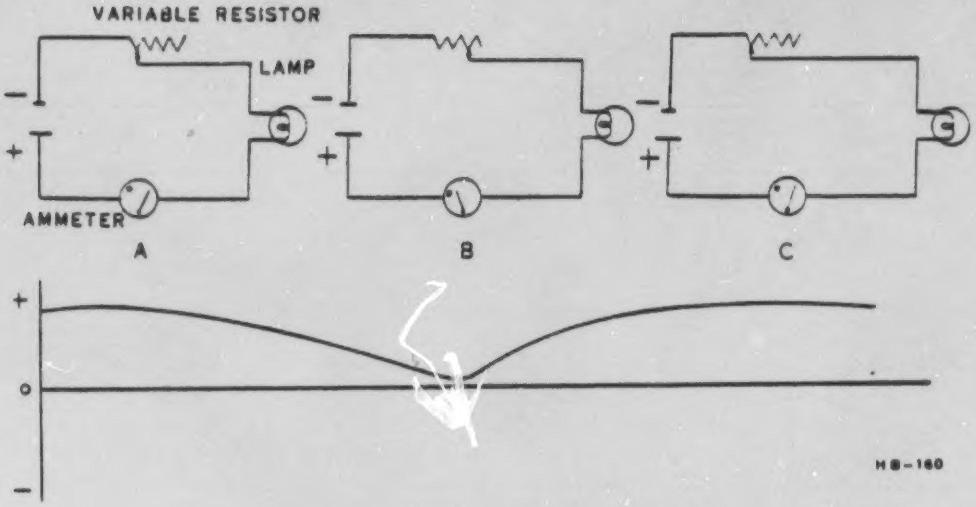


Figure 41. Resistance and current comparison.

compared with the total line resistance, that little receiver function resulted. The small current change did not produce enough difference in the magnetic field strength for the receiver to produce appreciable sounds.

16-10. *Induction coil.* Thomas Edison helped to correct the poor reception condition. He did this by installing an induction coil in the telephone so that the original (primary) transmitter current would flow only a short distance (see fig. 43). Thus, a change in transmitter resistance could create a relatively large change in the resistance of the primary circuit. This basic arrangement allowed battery current to flow through the transmitter, the primary winding of the induction coil, and back to the battery, as shown also in figure 43. You can see that a change in the transmitter resistance could cause a large current change in the primary circuit. Then, with the transmitter operating, a relatively large voltage was induced in the secondary winding of the induction coil, and a greater difference in line current was available to produce receiver action.

16-11. The coil shown in figure 43 is basically a transformer. Therefore, the voltage induced in the secondary circuit is determined by the coil design. That is, the type of core, turns ratio, etc., all have a bearing on the amount of induced voltage. This type of induction coil is the very thing that gave the early telephone the needed power for transmitting at greater distances. Not only was the induction coil used in early telephones, but it is still used today in most of our modern telephones Of course, it has had many refinements but it is still based on the same principles as those of the early telephone.

16-12. *Other refinements.* Comparing the simple circuit of figure 42 with the circuit of figure 44, we can see the additional units which are considered as refinements to the circuit. Accordingly, a push-type

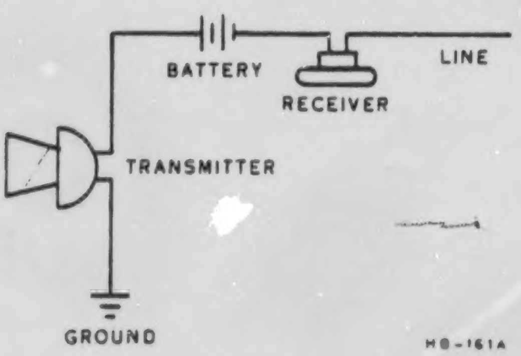


Figure 42. Circuit of early local-battery telephone consisting of receiver and transmitter.

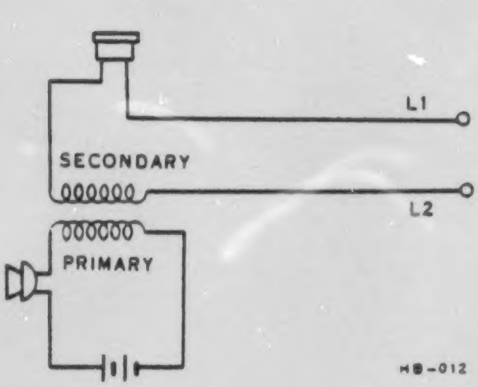


Figure 43. Basic primary and secondary circuits.

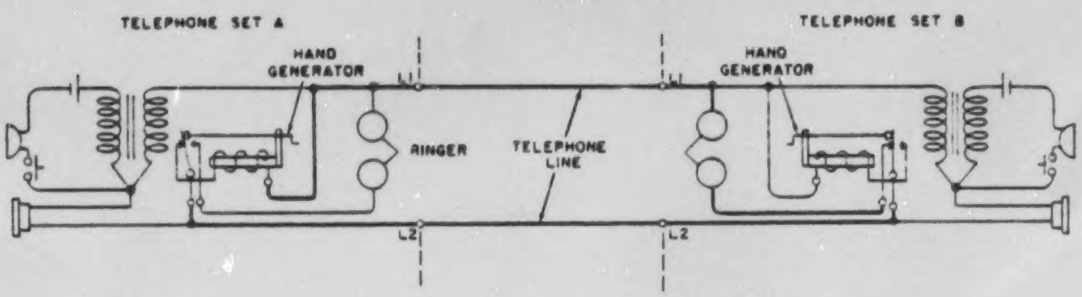


Figure 44. Signaling circuit of two local-battery telephone sets.

switch, a ringer, and a hand generator were added to the circuit. These devices enabled a person at either end to signal another party. The operated switch disconnects the transmitter from the line. The ringer, hand generator, and receiver are all connected to the line in this schematic. This connection provides that the operation of either hand generator will sound the ringers on the second telephone. We will discuss this circuit in more detail later.

16-13. Although the relative efficiency of the early ringer and generator is unknown, we can assume that their operation was similar to that of modern local battery generators and ringers. In modern telephony, the ringer is still a part of almost every telephone. With any local battery system that may still be in use, the hand generator is used with each telephone. Of course, with modern systems other than local battery, the ringing current is generated at the central office, and there is no need for a hand generator in every telephone. Since you studied and worked with these components at the resident course, there is no need for use to describe their construction nor illustrate them now. Let us now review the signaling circuit theory again.

16-14. **Signaling Circuit.** Figure 44 illustrates the signaling circuit of two local battery telephones. In this illustration, the hand generator switch of telephone B is shown in its normal position and the hand generator switch of telephone A is shown in the position it assumes while the generator is operating. To call telephone B, a person at telephone A first turns the crank of the hand generator. This closes the hand generator switch (as shown for telephone A in the illustration) and puts the hand generator across the telephone line. The hand generator then sends a 20-cycle ringing current to the ringer at B through the connecting circuit provided by the line and the hand generator switch of telephone B. When the person stops turning the hand generator at telephone A, the switch associated with this generator returns to its normal position, disconnecting the generator from the line and reconnecting the ringer. With both generator switches in their normal position, the system would then be in position for communications between the two telephones. Furthermore, when the generator switch at telephone A is returned to its normal position, the ringer of telephone A is reconnected to the line to place it in a position where it can receive ringing current from the generator of telephone B.

16-15. With the addition of a hookswitch in each telephone, the circuit shown in figure 44 could be considered as a complete local battery system. Of course, it lacks many of the modern telephone refinements, but it does provide for receiving, transmitting, and signaling, which are the basic requirements for telephony. The hookswitch, as mentioned previously, disconnects the transmitting and receiving components from the line when the receiver is placed on its hook.

16-16. Before we leave figure 44, note that each telephone is powered by a battery that is connected in series with the transmitter and the primary winding of the induction coil. Also, we noted the push-to-talk switch located in each primary circuit just below the transmitter. This switch saves battery current because it opens the primary circuit during the time that sound is being received.

16-17. While there are only two telephones shown in figure 44, it is possible to connect several to a telephone line in a local battery system. Of course, when several telephones are connected to the same pair of telephone lines, a coded ringing system must be used. This is necessary because the operation of any one of the hand generators on the line will operate the ringers on all of the telephones. For this reason, it would be necessary to assign a coded ring to each telephone on the line. Since this type of operation is not very satisfactory, a swtichboard is normally provided at some central point to switch the calls through to the desired telephone. Before we consider the switchboard, however, we need to discuss another factor about the circuitry of figure 44—the problem of sidetone.

16-18. **Sidetone.** As mentioned before, sidetone is the effect of hearing your own voice in the telephone receiver as you talk into the transmitter. The sidetone in a circuit such as that shown in figure 44 would be rather loud, because both telephone receivers are connected in a series circuit along with the secondary windings of both induction coils and the connecting telephone line. The voice current produced in this series circuit by a person speaking into the transmitter of either telephone passes through both receivers and is reproduced as a sound wave of speech in each one. Therefore, the persons using these telephones would hear their own voices reproduced in their own receivers.

16-19. In the telephone system shown in figure 44, the voice current in the telephone set of the speaker is greater than the voice current in the set of the listener, because the resistance of the telephone line opposes the voice currents, reducing their value before they reach the receiving end of the circuit. In addition, the voice current in the secondary winding is increased by the transformer action of the induction coil. This increased voice current, passing through the receiver of the speaker, further increases its output of sidetone.

16-20. The sidetone in a telephone should be at a level that promotes normal conversation. That is, you should hear your own voice in the telephone receiver with about the same volume as you hear it when having a normal conversation with someone. If the sidetone is completely eliminated from a telephone, the user then tends to shout just the same as a person who is hard of hearing. When the sidetone is too loud in a telephone set, it is undesirable for several reasons. First, the speaker will lower his voice when he hears it loudly in his own receiver. This reduction of sound input to the transmitter reduces the voice current output, which in turn reduces the current in the receiver of the distant telephone set. Second, when the sidetone is too loud, it tends to lessen the sensitiveness of the ear of the speaker to the more feeble voice current from the distant telephone set. Third, when a telephone set has too much sidetone, the local room noise is picked up by the transmitter and is heard by the listener along with the voice of the distant speaker. These noises, reproduced in the local telephone receiver, distract the listener and reduce the intelligibility of the words received from the distant station. This effect is particularly objectionable when the telephone is used in usually noisy locations. It should be apparent from the previous explanation that sidetone must be controlled in the telephone set. It must not be completely eliminated because that would be just as bad as having too much sidetone. The circuits used to reduce sidetone are called antisidetone circuits. There are many and various types of antisidetone circuits used in modern telephony, and we need to know something about their operating principles.

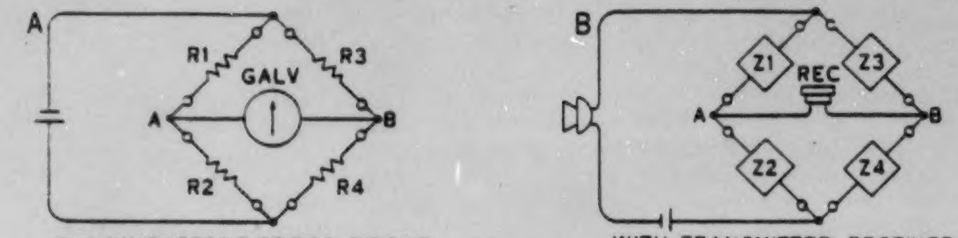
16-21. *Antisidetone circuit principles.* If we were to completely eliminate sidetone from a telephone set, the user would not be able to hear his voice in his own receiver. An ideal antisidetone circuit would be one in which the sidetone is completely eliminated. In actual practice, an ideal antisidetone circuit is not obtainable; and if it were, it would not be desirable, as we explained previously.

16-22. From your previous studies in Chapter 4, you should recognize A in figure 45 as being a bridge circuit. The four resistors, R1, R2, R3, and R4, are connected to a battery; and a galvanometer is connected between points A and B. The battery current in this circuit is supplied to resistor branches R1-R2 and R3-R4. With current in the circuit, there is a potential difference across each resistor. When the circuit is an unbalanced bridge with a potential difference between points A and B, current will then flow through the galvanometer. When the circuit is a balanced bridge with no potential difference between points A and B, the current will not flow through the galvanometer.

16-23. To continue with our explanation of antisidetone principles, refer to view B in figure 45. In this bridge circuit, the resistors are replaced by impedances, the battery is replaced by an ac generator, and the galvanometer is replaced by a telephone receiver. This arrangement is an ac bridge circuit, which, when balanced, passes no current through the receiver. When this circuit is balanced, there is no potential difference between points A and B; and, when it is unbalanced, there is a potential difference between points A and B. Furthermore, when this circuit is unbalanced, current then flows in the receiver. This circuit is in balance when the ratio of impedance Z1/Z2 is equal to the ratio of impedance Z3/Z4.

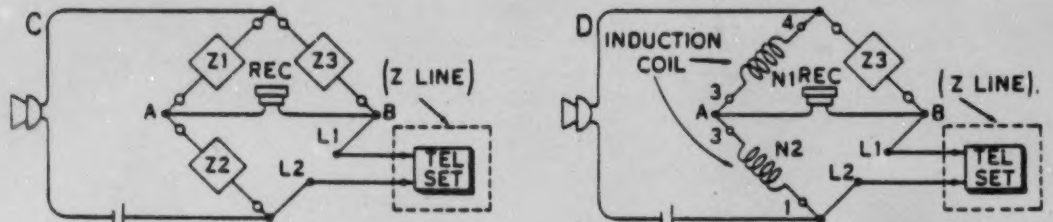
16-24. In view C of figure 45, the ac generator has been replaced with a telephone transmitter; and impedance Z4 has been replaced with the telephone line and a distant telephone set. Now, if we assume that the impedance ratio of Z1/Z2 is equal to the impedance ratio of Z3 over the impedance of the line and telephone set, there would be no potential difference between points A and B when a steady pitch is applied to the telephone transmitter. Consequently, the sound applied to the transmitter would not appear in the receiver, but it would appear in the distant telephone set. Furthermore, any electrical waves generated by the transmitter of the distant telephone set are applied to terminals L1 and L2 of this circuit. Therefore, they pass through the receiver and impedance Z2, actuating the receiver diaphragm.

16-25. By looking at views D, E, and F of figure 45, you can see how the balanced bridge principle applies when transformers or induction coils are used. With any of these circuits, the induced voltage caused by sound entering the transmitter is applied to the upper and lower terminals of a bridge circuit. Assuming that these bridge circuits are balanced, the sound does not appear in the receiver, but it does pass through the receiver of the distant telephone. Also, as mentioned previously, an incoming signal


A
R1
R3
GALV
A
B
R2
R4
B
Z1
REC
Z3
A
B
Z2
Z4

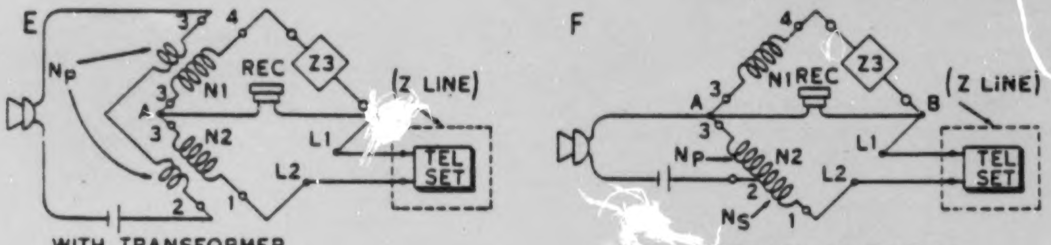
D-C WHEATSONE-BRIDGE CIRCUIT

WITH TRANSMITTER. RECEIVER AND IMPEDANCES


C
Z1
REC
Z3
(Z LINE)
A
B
L1
Z2
L2
TEL SET
D
INDUCTION COIL
4
N1
REC
Z3
(Z LINE).
3
A
B
3
N2
L1
L2
TEL SET
1

WITH TELEPHONE LINE AND SET

WITH INDUCTION COIL


E
3
4
Np
REC
Z3
3
N1
(Z LINE)
A
3
N2
L1
L2
TEL SET
2
1
F
4
N1
REC
Z3
(Z LINE)
A
3
B
3
Np
N2
L1
L2
TEL SET
2
Ns
1

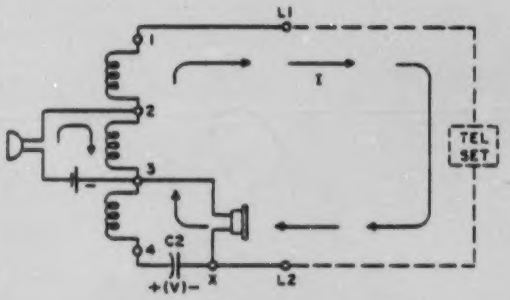
WITH TRANSFORMER

WITH AUTOTRANSFORMER-TYPE INDUCTION COIL

Figure 45. Development of antisidetone circuit.

from the distant telephone passes through the receiver because it is applied to terminals L1 and L2 rather than across the bridge circuit. To carry this explanation a little further, let's consider the operation of a local battery telephone circuit.

16-26. *Antisidetone circuit operation.* The circuit illustrated in figure 46 represents a local-battery telephone with an autotransformer type induction coil. This same circuit is represented by view F in figure 45. In both illustrations, note that the primary winding of the induction coil is located between terminals 2 and 3—the secondary includes all three windings from terminal 1 to terminal 4. When current is on the increase in the primary circuit, as shown by the arrow in figure 46, a voltage is induced in the secondary from terminals 1 to 4. At the instant when terminal 1 of the secondary is negative and terminal 4 is positive, electons move from terminal 1, through the line circuit, the distant telephone, and back through the other side of the line circuit to capacitor C2. If you will notice, positive is applied to the other side of capacitor C2 from terminal 4. Thus, current flows from the secondary winding through the receiver of the distant telephone. It does not flow through the receiver from terminal X to terminal 3, however, because both of these terminals are of equal but opposite potential at the same time. Furthermore, during an alternation in the opposite direction, both of these potentials also cancel. Thus,


L1
1
I
2
TEL SET
3
4
C2
+(V)−
X
L2

TRANSMITTING

Figure 46. Antisidetone action.

the antisidetone circuit holds sidetone to a minimum during transmission.

16-27. We mentioned earlier that there should be some sidetone to promote normal conversation over the telephone. If the antisidetone circuits just described were perfectly balanced for a given frequency, they would probably eliminate most of the sidetone at that one frequency. For frequencies other than the one where balance is obtained, the circuit is partially unbalanced. Therefore, when the various frequencies of the audio spectrum are applied to the telephone circuitry, some sidetone is heard in the receiver. The components of the modern telephone are designed and constructed in such a manner as to produce the proper amount of antisidetone. This is assuming, however, that the telephone system and circuitry is maintained in proper order.

16-28. **Local-Battery System.** You have learned that with local-battery telephony, where each telephone is powered by its own batteries, a simple telephone system may consist of two or more telephone sets connected to a telephone line. The telephone line, of course, would normally be two wires: referred to as a pair. To have practical communications between several telephones, however, requires that a telephone line from each telephone be connected to a central switching point. At this central point, the call from an individual telephone can be switched through to any one of the other telephones in the system. With most of our modern telephone systems, the calls are switched through automatically by the central office switching equipment. Yet, some calls are switched through by an operator using a telephone switchboard. To continue with our explanation of local-battery telephony, let's briefly discuss the circuit of a small, portable type switchboard.

16-29. Using the incoming line circuit of figure 47, we can see that an incoming signal to the switchboard passes over L1 and L2 and operates the I201 relay. This operated relay actuates a drop (represented by a Z and labeled "To Night Alarm Circuit"). Of course, for this circuit to work you must properly connect the incoming line to terminals L1 and L2. Further, you also have responsibility for the telephone station equipment. We have said that the subset for a local-battery system requires a battery. You will likewise maintain these subsets. Since the jack (J201) and its parallel connected plug are part of the local-battery switchboard, you may also be inspecting them. You should normally have to perform very little maintenance on the plug, jack, or CR201 diode.

16-30. You know now that most of the telephone systems in the Air Force are common-battery type. Therefore, you may have little opportunity to care for the former local-battery type. Before we review common-battery principles, let's summarize a few points about the local-battery system. The term "local" means that the sources of electrical energy for the transmitters and for signaling are a part of the telephone subset at each individual telephone station. A local battery supplies the current for the transmitter circuit, and a hand generator or magneto supplies the current for signaling. The local-battery telephone subset is actually a self-powered unit in that it requires no power from the central office for operation. Therefore, it can be used in conjunction with another local-battery telephone without being connected to a central office.

17. Common-Battery Telephone Principles

17-1. The chief difference between common- and local-battery telephone systems is in the way the electrical energy is supplied for operation of the

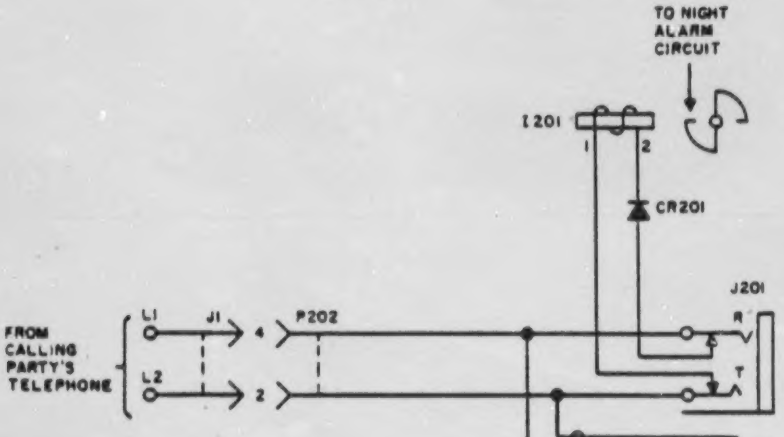


Figure 47. Incoming line signal circuit.

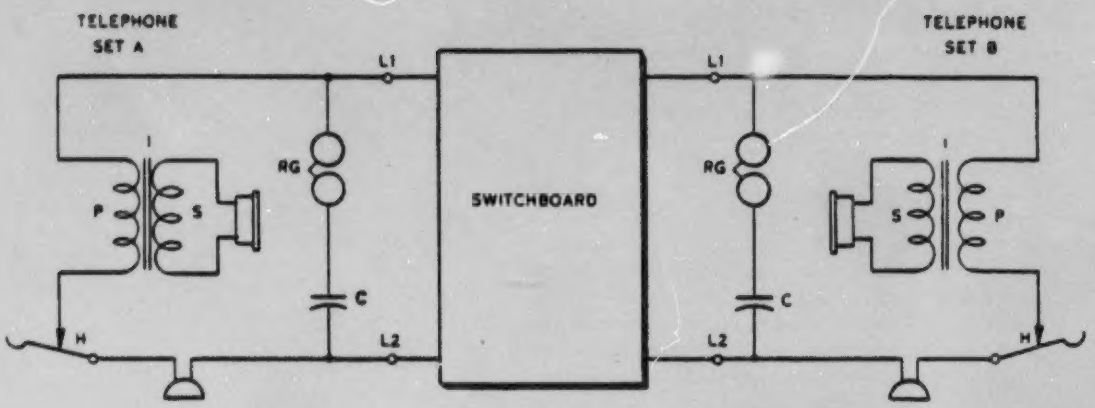


Figure 48. Basic circuit of common-battery telephone system.

system. As explained previously, every telephone in a local-battery system operates on its own batteries. In a common-battery telephone system, a centrally located storage battery or power supply is used in place of the individual dry cells required at each telephone station in a local-battery system. This central power source (located at the central office) serves all of the telephone stations in a common-battery system.

17-2. Most of the telephone systems used in the United States are of the common-battery type. Furthermore, these common-battery systems may be divided into two basic categories: manual and automatic. With manual common-battery systems, the telephone calls are switched through manually by operators. With automatic systems, the calls are switched automatically by central office equipment in response to the numbers dialed on customers' telephones. It goes without saying that most of our systems are of the automatic (dial) type, since they offer more satisfactory service to the customer and the industry.

17-3. As you may have expected, many of the components of common-battery systems are identical with, or at least similar to, the corresponding local-battery components. Since the station equipment for both manual and automatic systems is covered in Volume 2 of this course, we will not discuss this equipment in this section. We will, however, discuss some of the general features of the common-battery systems.

17-4. **Basic Common-Battery Circuit.** The basic circuit of a common-battery system is shown in figure 48. In this circuit, each telephone is equipped with an induction coil (I), a hookswitch (H), a capacitor (C), a ringer (RG), a transmitter, and a receiver. When the hookswitch is in the position shown, current flows from the switchboard battery through telephone line (L1), the primary winding of induction coil (I), the hookswitch, the transmitter, and line L2 back to the switchboard battery. With the circuit in this condition, sound waves entering the transmitter cause the line current to vary all the way from the telephone to the central office. Furthermore, if the telephone sets are connected through the switchboard, the sound waves entering the transmitter of either telephone will be heard in the receiver of the other telephone set. The circuitry shown in figure 48 may be considered in three parts: the primary, or transmitter, circuit; the secondary, or receiver, circuit; and the ringing circuit.

17-5. *Primary circuit.* As explained in the previous paragraph, the primary circuit consists of the transmitter, the hookswitch, the primary winding of the induction coil, and the circuitry to terminals L1 and L2. The hookswitch closes this circuit whenever the receiver is lifted from its hook or cradle, as when the user lifts it to either answer or make a telephone call. When the user places the receiver back on its hook or cradle, the hookswitch opens the primary circuit, disconnecting it from the central office battery.

17-6. *Secondary circuit.* As shown in figure 48, the secondary circuit consists of the receiver connected in series with the secondary winding of the induction coil. As was explained for the local-battery system, variable dc in the primary winding of the induction coil induces an alternating current in the secondary winding and receiver. Thus, when either transmitter is spoken into in the system shown in figure 48, the sound is heard in the receivers of both telephones. Of course, in modern telephone systems, antisidetone circuitry is used to control the level at which the speaker hears his own voice in the receiver.

17-7. *Ringer circuit.* In figure 48, notice that when the hookswitch is open, the primary circuit is disconnected from the switchboard battery. In other words, the telephone primary circuit from L1 to L2 is open. The ringer circuit, however, through ringer RG and capacitor C, is still a complete path for central office ringing current. Therefore, when ringing current from the switchboard is applied to terminals L1 and L2 via the telephone line, it passes through capacitor C and ringer RG, to ring the called telephone. It should be noted that capacitor C will not pass direct current—therefore, it prevents the ringer RG from shorting the switchboard battery. This is important in common-battery telephony, because without capacitor C, the telephone ringer would be a continuous drain on the switchboard battery.

17-8. **Signaling the Switchboard.** As illustrated in figure 48, there is no hand generator in the common-battery telephone set. In common-battery telephony it is not necessary to use an ac ringing current to signal the telephone office. Since lifting the receiver from its cradle allows the hookswitch to complete a circuit to the central office battery, a light connected in series with this circuit at the switchboard will illuminate whenever the receiver is lifted. Thus, the operator, at a manual common-battery switchboard, is signaled by the lighting of a lamp whenever a customer lifts his telephone receiver from its cradle.

17-9. With the automatic common-battery system (dial telephony), removal of the receiver from its cradle allows the hookswitch to complete a circuit to the central office battery through a line relay in the switching equipment. The operation of this relay connects the calling telephone through to the dial switching equipment. Thus, when a customer lifts his receiver, he is automatically connected through to the central office. He is then informed of this connection by the reception of dial tone in his receiver.

17-10. This ends our discussion of telephone fundamentals. The next volume of this course pertains to telephone station equipment, including its construction and repair. Before you study the next volume however, it is recommended that you answer the review exercises pertaining to this one. Remember, the better you understand the fundamentals of electricity and telephony, the easier it will be for you to complete the following volumes in this course.

Glossary

Adapter—A device which is designed to complete connections between jacks, plugs, or receptacles by means other than those originally intended.

Alinement—The process of adjusting a circuit so that it will be responsive to a desired frequency or range of frequencies. Also, the adjustment procedure for components of a system so that their functions are synchronized.

Alligator Clip—Long, narrow spring clip with meshing jaws, primarily used with test leads for making temporary connections.

Amplification—Increase of magnitude in a signal from one point to another. It may be expressed as a ratio, or by extension of the term, in decibels.

Amplified Back Bias—Voltage developed across a fast time-constant circuit within an amplifier stage and fed back into a preceding stage.

Amplifier Classes—The circuit conditions that provide a specific bias for controlling the circuit current has resulted in the term "class" for amplifiers. Among the classes are A, AB, B, and C.

Anode—Positive electrode toward which electrons and negative ions are drawn.

Antiresonant Circuit—Parallel-resonant circuit.

Antisidetone—Arrangement of a telephone circuit where a small amount of power from the transmitting circuit is returned to the associated receiver.

Arcing—Spark jumping as can be seen at motor brushes or switch contacts.

Astable Multivibrator—A circuit that can switch rapidly from one status to another. Also spoken of as free running.

A-Supply—A voltage (power) supply which is of lower rating than the B-supply. It is used with electronic circuits.

Audio—Frequency that can normally be heard. Audiofrequencies range from 20 to 20,000 cycles per second.

Automatic Switching—Connections that are made by using remotely controlled switches.

B-Battery—Dc voltage supply for plate and screen grid electrodes.

Back Electromotive Force—Voltage developed in an inductive circuit by a changing current. The polarity of the induced voltage is opposite the applied voltage.

Base—The center semiconductor region of a double junction transistor. It is comparable to the grid of an electron tube.

Battery—Series of cells which produce electric current from chemical elements.

Bias—Electrical, mechanical, or magnetic force which is applied to a relay, vacuum tube, or other device, for the purpose of establishing a reference level for the operation of the device.

Binding Post—Terminal for connecting a conductor.

Bistable Multivibrator—A circuit which requires two input pulses to complete a cycle.

Bleeder—A resistor connected to improve voltage regulation, to remove the charge for a capacitor, or to protect equipment from excessive voltage after the load is removed.

Blocking Capacitor—Capacitor which limits low-frequency current without materially affecting the high-frequency current.

Bridge Circuit—Device which is used to measure electrical opposition by comparing a known circuit with the unknown.

Bridge Rectifier—Rectifier which has four elements arranged to provide full-wave rectification of alternating current.

Bucking Voltage—Opposing voltage.

Buffer Amplifier—A circuit designed to isolate a preceding circuit from the following circuit.

Bypass Filter—A circuit which provides a low attenuation shunt around some equipment devices.

Cable—An assembly of one or more conductors included within a protective sheath, thus permitting use of the conductors separately or in groups. Cable may be suspended by poles or towers (aerial) or installed in underground (buried).

Calibration—Process of comparing an instrument with a standard to determine its accuracy or to devise a correct scale.

Capacitive Reactance—Opposition offered to alternating current by capacitance, expressed in ohms.

Capacitive Coupling—Association of two or more circuits through use of capacitance.

Carrier—High-frequency current superimposed on a voice current and on which additional frequencies can be modulated. Provides for the transmission of more than one type of intelligence simultaneously.

Cascade Amplifier—A circuit with several stages in which the output of one is fed into the input of a second.

Cathode Follower—An electronic circuit in which the output load is connected to the cathode circuit.

Classification System—Using a common qualifying base to arrange groups. Also, the groups are arranged to form a specific scheme.

Classified—A designation for official information which is to be protected in the interest of the Nation's defense.

Collector—The component of a transistor that compares to the plate of an electron tube.

Composite Cable—Cable in which conductors of different gages or types are combined within one sheath.

Confidential—Classification authorized for defense information or material which, if disclosed, is prejudicial to the defense interests of the Nation.

Continuity—The presence of a complete electrical circuit.

Corrosion—Eating away (dissolution) of metal by acid type chemicals.

Coulomb's Law—A law which states that the force between unlike charges is an attraction, between like charges a repulsion.

Coupling—Association of two circuits so that electrical energy may be transferred from one to the other.

Dead—Having no connection to any source of voltage.

Detector—Device which uses a carrier current while controlling a lower frequency unit.

Dial Pulse Springs—A pair of normally closed springs of a dial assembly, which is opened and closed by a pulse cam. The number of times that they open corresponds to the digit dialed.

Dial Shunt Springs—Set of contact springs of a dial assembly which shunt the receiver and transmitter of a telephone set whenever the dial is off normal (operated). Shunting of the receiver prevents pulse clicks from being heard during dialing while shunting of the transmitter prevents a variable resistance from affecting the generated pulses of the dial in the line loop.

Dial Switching Center—Communication building where automatic telephone and teletypewriter equipment is placed which connects two or more users together for communication purposes.

Diode—A device which changes alternating current into a pulsating direct current. Also called a rectifier.

Electronic—Work done by the movement of electrons.

Emitter—A transistor electrode from which the carriers depart.

Equipotential—Having the same potential at all points.

Feedback—Returning a fraction of the output signal to the circuit input.

Fixed Bias—Voltage of a constant value.

Flags—Codewords, nicknames, and short titles for special subjects.

Flux—Term used to designate collectively all the electric or magnetic lines of force in a region.

Four-Wire—A two-way circuit using two paths arranged so that the communication currents are transmitted in one direction on only one path and transmitted in the opposite direction on the other path. The circuit arrangement may or may not include four wires.

Frequency—Number of electrical changes in a period of time.

High Resistance Junction—Union of conductors which is faulty, thus reducing the circuit current.

Hole—A mobile vacancy in the electronic structure of a transistor which acts as the positive point in the device.

Hydrometer—Float and marked container used in measuring specific gravity of a storage battery electrolyte.

Impedance—Total opposition to alternating current.

Inductance—The property of an electrical circuit which provides an opposing voltage to current changes, either in the circuit itself or in a neighboring circuit.

Inductive Coupling—Association of one circuit with another by means of inductance that is common or mutual to both.

Infinity—Having a resistance that is too great to measure.

Insulate—To separate from other conductors with a high-resistance material.

Interlock—A circuit in which one action cannot begin until one or more other actions have occurred. The interlocking action is generally obtained with relays.

Interrupter—Magnetically operated device for opening and closing an electric circuit rapidly and periodically.

IR Drop—Voltage drop across a resistor produced by current in the resistor.

Jack—Stationary part of a circuit connector.

Jumper—Short length of conductor used to connect terminals or used to connnect around a break in a circuit. It is usually a temporary connection.

Kc—One thousand cycles per second (kilocycle).

Kirchoff's Laws—The sum of the current flowing to a given point in a circuit is equal to the sum of the current leaving that point. Also, the algebraic sum of the voltage drops in any closed loop of a circuit is equal to the algebraic sum of the electromotive forces in that circuit.

Lead—A wire to or from a circuit element.

Legend—Symbols or other data placed near a diagram to assist in determining the proper interpretation.

Lenz' Law—Current induced in a circuit as a result of its motion in a magnetic field is in such a direction as to exert an opposing force to the motion.

Linear—Having an output which varies in direct proportion to the input.

Line Balance—Matching impedance, equaling the impedance of the line at all frequencies, when terminating a two-wire line.

Loading—Connecting a power consuming device to a circuit.

Loading—Insertion of reactance in a circuit for the purpose of improving its transmission characteristics in a given frequency band.

Locking—Keeping a device operating following the opening of the originating circuit. The term "hold" is also used to identify this second operating circuit.

Loop—A closed electrical circuit.

Loop Pulsing—Regular, momentary interruptions of the direct current in a closed electrical circuit.

Low-Pass Filter—Arrangement of components which passes all frequencies below a specified frequency with little or no loss but discriminates against any higher frequency.

Main Distributing Frame—Unit used for connecting the outside telephone lines to the switching center equipment. It also supports protective devices and functions as a test point.

Manning Document—Official paper showing all authorized positions for an organization.

Mc—One million cycles per second (megacycle).

Milli—One thousandth of a unit.

Monitor—Checking the performance of a device, unit, or system by examining a sampling of the output.

Multiple—Connected in parallel.

Mutilation—Process of making a document unrecognizable and preventing its information from being reconstructed.

Mutual Induction—Inducing a voltage into one circuit from a neighboring circuit that is magnetically coupled with it.

Node—Zero point; for instance, an electrical point which has no current has been referred to as a current node.

Ohm's Law—$E = IR$, or $I = E/R$, or $R = E/I$.

Ohmmeter—Instrument for measuring resistance in an electrical circuit.

Open Circuit—A circuit which is not complete.

Open-Circuit Voltage—Voltage at circuit terminals when no appreciable current is in the circuit.

Patch—To connect circuits together temporarily by means of a cord with plugs, which is known as a patch cord.

Pawl—A device designed to fit into notches on its mating device.

Plant—The installed facilities which provide communications by electronic means.

Plug—Removable part of a circuit connector.

Polar Relay—A device that has a permanent magnet that centers the armature. The armature movement is determined by the direction of current in the windings.

Polarity—Condition in an electrical circuit by which the direction of the flow of current can be determined.

Potential—Difference in voltage between two points in an electrical circuit.

Potentiometer (POTS)—A three-terminal resistor which has one or more sliding contacts and thus functions as an adjustable voltage divider.

Preoperational—Before telephone equipment is "cut over."

Preventive Maintenance—Care of equipment that prevents future troubles.

Primary—First.

Primed—Act of making a device ready to operate.

Probe—Test lead used for checking electrical circuits.

Pulsing Relay—Device which reacts rapidly when there is a sudden change in its operating circuit.

Pulse Repeater—A device which receives pulses and reflects them into a second circuit.

Punching—Metal stampling designed to permit a connection to a conductor by means of solder.

RC Coupling—Placing resistors and capacitors in a particular arrangement so that they form a connection between two circuits.

Reciprocal—Method for determining resistance in a parallel circuit.

$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Regenerative—Process by which a part of the power in the output circuit of an amplifying device is returned to the input circuit so that the initial power is increased.

Repeating Coil—A device, such as a transformer, which receives signals from one circuit and retransmits them to another circuit.

Residual—Magnetism which remains in a unit after removal of the magnetizing force. Also the name for a screw that is placed between relay armature and coil core which prevents residual magnetism from holding the armature operated after the operating circuit is opened.

Resistance—Opposition which a device or material offers to current in an electrical circuit.

Resonant Frequency—The frequency at which the inductive reactance is equal to the capacitive reactance.

Ringdown—Circuit signaling where the signaling and supervision is controlled by a ringing current.

Secret—Information or material which, if disclosed, could result in serious damage to the Nation. For example, the release of information that shows the location of troops who are engaged in war.

Sensitive—All classified information is sensitive. Unclassified information, which reveals classified plans when used with other information is also sensitive.

Series-Resonant Circuit—A circuit which has the power source in series with capacitance and inductance whose reactances cancel each other at the applied frequency.

Short Circuit—Low-resistance connection between two points, usually accidental. It results in excessive current which may damage the equipment.

Shunt—Two or more electrical devices connected so that the current may divide between them.

Slow-Operated Relay—A relay designed to act slowly following completion of its operating circuit.

Slow-Releasing Relay—A relay having a time delay in which there is an appreciable delay between the opening of the operating circuit and the release of the armature.

Sneak Current—Current which, while not particularly excessive, is above the normal specification for the equipment circuit. As a result it can produce heat damage to the components.

Solder—Alloy of lead and tin used in making circuit connections.

Specifications—Prepared engineering information for telephone equipment.

Spring Pileup—The assembly of all contact springs which are operated by an armature.

Static Electricity—Electricity that is on an object and which normally has no way to leave it. When a second object is brought near, electrons jump between the two.

Telephone Tapping—Connecting to a telephone circuit so that information can be withdrawn. For our purpose, this act is illegal.

Teletype—Transmitting system which uses a keyboard for sending and receiving typewritten messages.

Terminal—Final device or station in a system.

Termination (4-wire)—Connecting a load to a 4-wire line circuit.

Thermistor—An electronic device which changes resistance with a change in temperature.

Top Secret—Information or material which, if disclosed, could result in exceptionally grave damage to the Nation. If a disclosure would result in an armed attack on the Nation, for example, the information would be classified TOP SECRET.

Transient—Instantaneous surge of voltage which results from a circuit change.

Trunk—Communications channel between two offices or between groups of equipment within the same office.

Tuned—Adjusted to operate at a specific frequency. It also describes a circuit that consists of inductance and capacitance which can be adjusted for resonance at a desired frequency.

Unclassified—Information which need not be protected but may be subject to security safeguards.

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Unidirectional—Effective in one direction only.

Varistor—Device whose resistance lowers when the voltage increases. It is used to shunt harmful voltage away from circuit components.

Vault (cable)—A building repository where communications cable are spliced together.

Verify—To insure that the connections or actions are correct.

Vernier—Device applied to the graduated scale on many instruments which permits accurate adjustment or which enables the repairman to make a more precise reading.

Voltage—Term used to identify electrical pressure.

Voltage Divider—Resistor or resistors which provide adjustment by which a parallel connected load can receive a required voltage value.

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TELEPHONE EQUIPMENT INSTALLER-REPAIRMAN

(AFSC 36254)

Volume 2

Telephone Construction and Repair

Extension Course Institute

Air University

Preface

THIS SECOND volume of Course 36254, *Telephone Equipment Installer-Repairman*, continues with Common-battery Telephony. It explains both the manual and automatic systems, the basic principles of central office switching, and describes telephones and telephone components. The switching principles are provided only to help you understand the operation of the telephones and their components. In addition, this volume has information about telephone troubleshooting, maintenance and repair, and the inspection system records.

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Station Equipment for Common-Battery Systems

THE TELEPHONE equipment installer-repairman, as you already know, must install, troubleshoot, and repair telephones and telephone circuits. To do this he must have an understanding of various telephone systems, circuits, and components. In Volume 1, we discussed the principles of electricity and described the basic circuits and components for sound-powered and local-battery systems. Furthermore, the basic principles for common-battery telephony were also briefly described.

2. Volume 2 continues the discussion of fundamentals, showing how they are applied in manual common-battery and automatic systems. Furthermore, Volume 2 covers telephone station maintenance, troubleshooting and repair, and the use of special tools and equipment for testing components and circuits.

3. This chapter discusses the telephones used with manual common-battery systems, and the operation of their parts and components. The material in this chapter has been arranged in the following sections: Telephone Components, Comparison of Local Battery and Common-Battery Systems, and Common-Battery Telephone Circuits.

1. Telephone Components

1-1. The modern telephone in general use today has the following major components:

a. Handset. This unit houses the transmitter and receiver; and, as you already know, you hold it in position at your ear and mouth.

b. Handset Cord. This cord extends from the handset to the circuitry in the telephone housing. It generally contains either three or four conductors which connect the receiver and transmitter to the circuits in the telephone housing.

c. Telephone Housing Assembly. This assembly houses the components used in receiving, transmitting, signaling, etc. With the dial and manual common-battery systems, the ringer, hookswitch, induction coil, capacitors, and either a dial blank or a dial assembly are in the telephone housing.

d. Mounting Cord. This cord extends from the circuitry of the telephone housing to the connecting block. At this point it is connected to a circuit that extends to the protector block and to the outside lines and cables. The mounting cord usually contains three or more conductors, depending on the system and the type of telephone circuits used.

1-2. Before we discuss manual common-battery systems and telephones, let's first consider the development and use of some of the main telephone parts. Since the hand generator and ringer were covered in Volume 1, the information is not repeated here. The main parts to be considered in this section are the transmitter, receiver, induction coil, and the capacitors. We will consider the transmitter first because it is the unit which transforms the sound waves into electrical impulses. Secondly, we will consider the receiver because it is the unit which receives the electrical impulses and converts them to sound waves. Thirdly, we will discuss the induction coil because it is used in conjunction with the transmitter and receiver. We will discuss capacitors last because they may be used in conjunction with the other telephone components.

1-3. **Transmitters.** In Volume 1 we said that the solid back transmitter, developed to increase telephone efficiency, came into being when batteries were first used in commercial telephone systems. Of course, this forerunner of the modern transmitter was developed from the Blake transmitter. Blake's concept (a transmitter should vary the strength of an existing current) is still being applied, and the solid back transmitter works on this principle.

1-4. In figure 1 movement of the diaphragm changes the pressure on the carbon granules in step with any activating sound waves. When the

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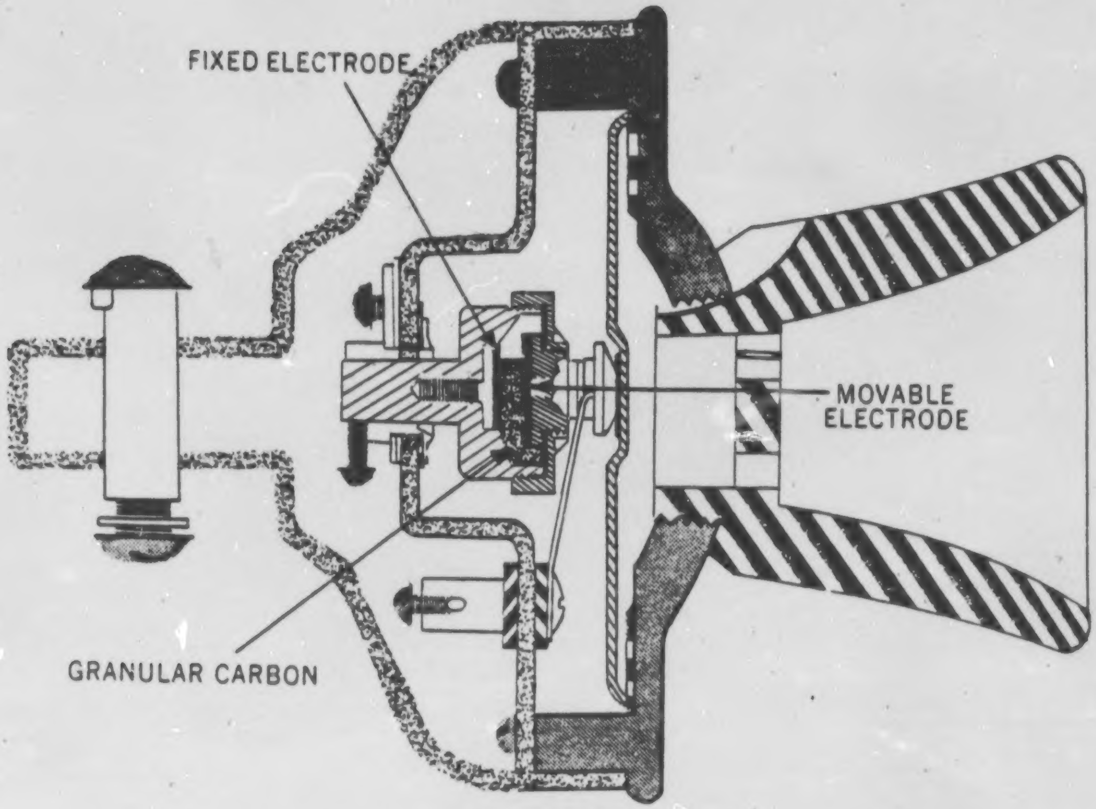

Figure 1. Solid back transmitter.

transmitter is connected into a circuit, these pressure changes vary the current through the transmitter, because the resistance between the grains of carbon varies inversely with the pressures placed on the carbon. In other words, if two pieces of carbon in a circuit are pressed firmly together, more current flows across the contact than when they are pressed lightly together.

1-5. When several small pieces of carbon are placed in series in a circuit, a very small change of pressure on them causes a large change in their resistance. By increasing the pressure sufficiently, the resistance of carbon granules may be made almost negligible. In the transmitter a large diaphragm is connected to the flexible cover of a cup containing carbon granules. This diaphragm provides a large surface for sound waves and increases the effectiveness of the transmitter. As previously stated, the vibration of the transmitter diaphragm varies the current through the transmitter according to the resistance within the carbon cup.

1-6. The solid back transmitter, although it was used for many years, was not too satisfactory with the carbon arrangement shown; the carbon granules formed a looser contact at the top than at the bottom of the cup. Then, even though the action of the diaphragm tended to move the carbon grains as desired, the instrument had to be held upright. If the instrument was tipped in any direction different from the position for which it was designed, the movement of the carbon granules tended to create a "frying" noise in the receiver. So the solid back transmitter functioned best when used with the old desk-stand telephone. It is unsuited to modern telephones.

1-7. With the development of handsets a transmitter adapatable to different positions became a necessity. The carbon cup transmitter, shown in figure 2, had a dual advantage: it could be moved in any direction without carbon granules moving about in the cup, and the shape of the carbon chamber and position of the electrodes prevented the carbon granules from packing together within the cup. In general, this transmitter overcame many of the objections of previous transmitters, and its frequency response was much more uniform. In fact, the whole transmitter was more efficient than any other had been. The reason was certain improved devices (contactors and insulators).

1-8. Figure 3 shows a handset equipped with a modern transmitting unit. The diaphragm, constructed of a thin aluminum alloy, is supported by paper on the edges; and a silk, moisture-resistant membrane stretched across the front of the transmitting unit protects the parts of the unit from the condensed moisture of the speaker's breath.

1-9. Because the modern transmitting unit has only a few parts and is assembled at the factory by stamping and pressing operations, it cannot be repaired by field forces. If the transmitter unit of a telephone is bad, it must be replaced with one of the proper type.

1-10. Our discussion of transmitters would not be complete without mentioning that special-purpose transmitters have been designed and supplied to service units. One of the special-purpose transmitters used during World War II was the differential transmitter which was worn

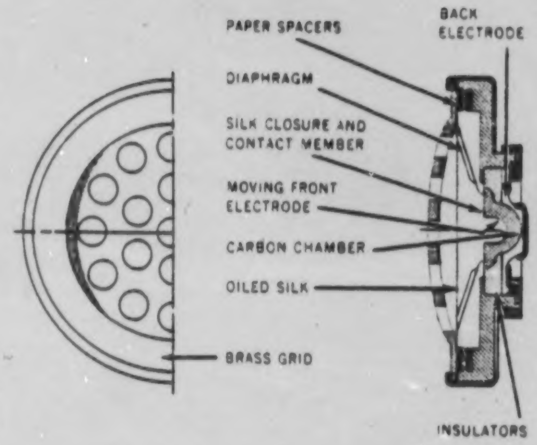
PAPER SPACERS
BACK ELECTRODE
DIAPHRAGM
SILK CLOSURE AND CONTACT MEMBER
MOVING FRONT ELECTRODE
CARBON CHAMBER
OILED SILK
BRASS GRID
INSULATORS

Figure 2. Carbon cup transmitter.

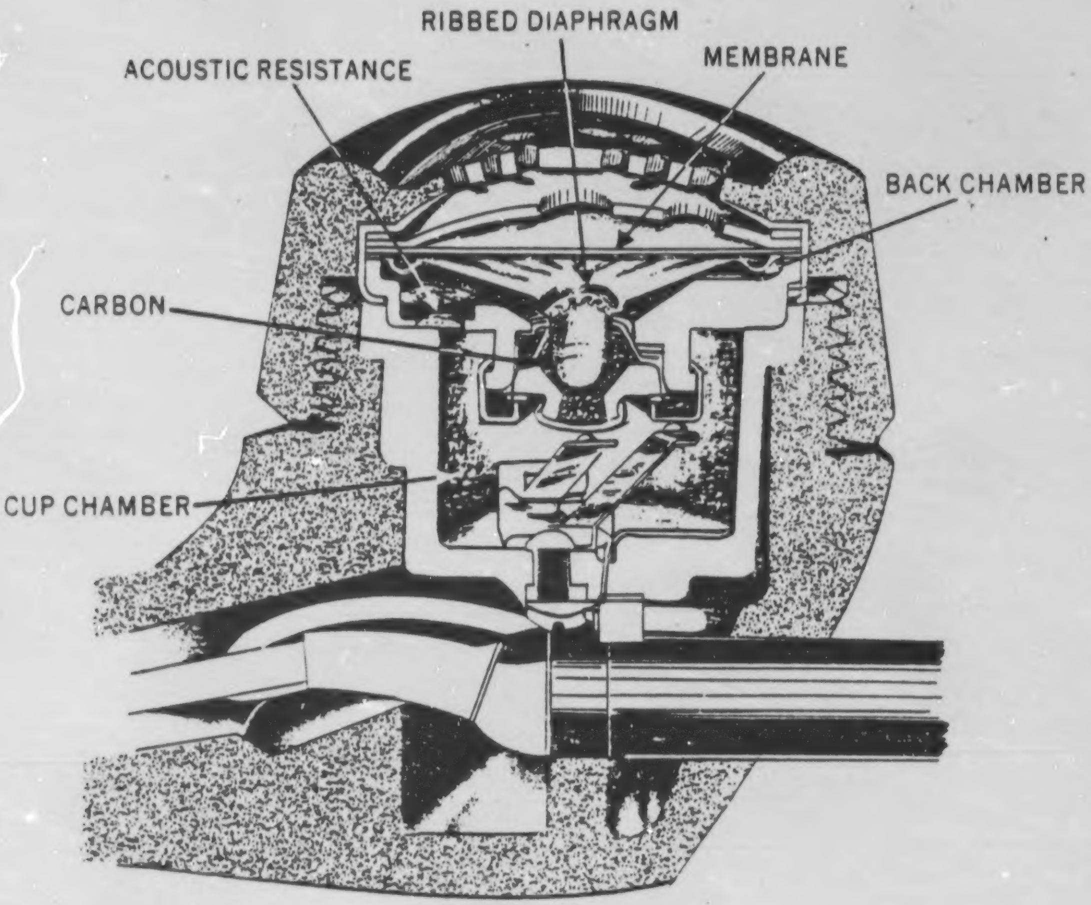
RIBBED DIAPHRAGM
ACOUSTIC RESISTANCE
MEMBRANE
BACK CHAMBER
CARBON
CUP CHAMBER

Figure 3. Transmitter (cut away view).

47 directly in front of the speaker's lips. It is commonly called a noise-canceling transmitter, because noises entering from the side or back of the transmitter are canceled out, and only those noises which enter directly from the front are transmitted. As you can see, this noise-canceling feature has the advantage of eliminating sounds of gunfire or other communication-disturbing noises of battle.

1-11. Most differential transmitters operate by equalizing the pressure exerted on the face of the diaphragm. This equalizing is possible because of the structure of the transmitter and the arrangement of the acoustic openings and airspaces about the transmitter diaphragm. The resulting diaphragm motion from distant sounds is, therefore, practically zero. Side sounds cause almost no change in the resistance of the transmitter carbon granules, and thus cause no perceptible change in the transmitting current.

1-12. **Receivers.** Receiver development has been a continuing development. Figure 4 shows the components of a receiver so that we can describe its operating principles.

1-13. The receiver principle is still the same—magnetic forces from an electric current create sound waves which match in shape the original sound waves striking the transmitter.

1-14. To produce the sound waves, the telephone receiver uses magnetic forces resulting from the strength of the current received. This current is to be found in the winding (see fig. 4). The magnetism strengthens or weakens the pull of a permanent magnet on the receiver diaphragm. (See bar magnet, pole piece, and diaphragm in figure 4.) The basic receiver function is shown in A, B, C, and D of figure 5. In A the diaphragm is deflected only by the pull of the permanent magnet, because no current is in the coil winding. In B the current strengthens this magnetic pull, and an increased diaphragm deflection results. In C decreased diaphragm deflection results from a reversed current which opposes the pull of the permanent magnet.

1-15. Continuous current alternations would produce a wave shape similar to that shown in the top portion of figure 5,D. If the receiver did not have a permanent magnet, however, such current reversals would not produce an alternating wave shape (sound wave). The resulting wave shape in that case would be the one shown in the lower portion of figure 5,D. As you can see, the permanent magnet in the receiver has a great effect on the shape of the sound wave produced by the receiver. Without this magnet a sound wave similar to an ac wave would not be reproduced.

1-16. During every telephone conversation the modern receiver diaphragm fluctuates many times each second between the condition shown in figure 5,B, and that in figure 5,C. This fluctuation is caused by receiver current transmitted from the distant station. This fluctuation, then, produces sound waves which match the sound wave of the speaker's voice.

1-17. The flat receiver unit (fig. 6) in the handset is the result of recent telephone engineering. More effective sound characteristics are obtained with this receiver than were possible without the new magnet arrangement. The ring-shaped pole piece concentrates the magnetic lines of force near the diaphragm. You can see the

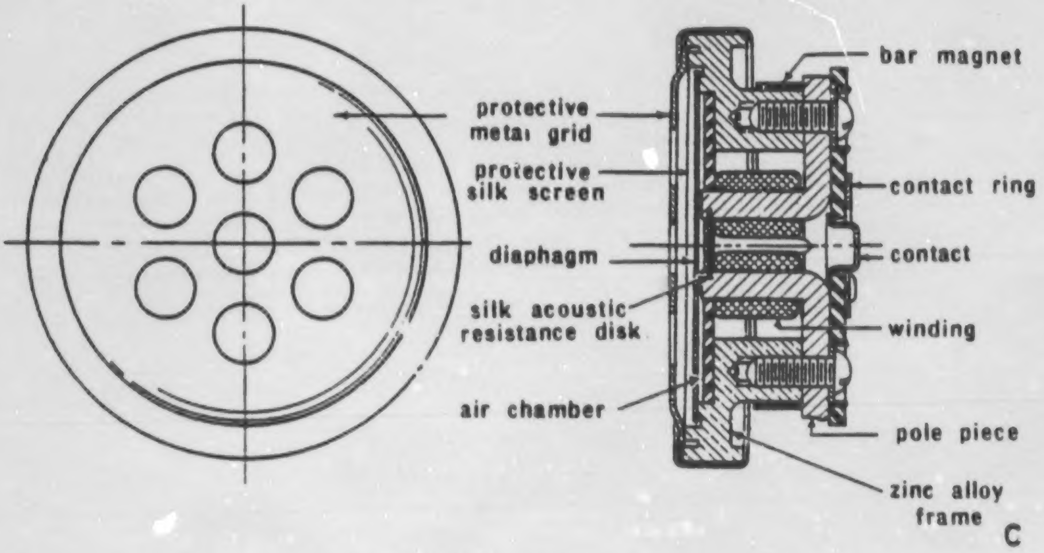

Figure 4. Receiver (cut away view).

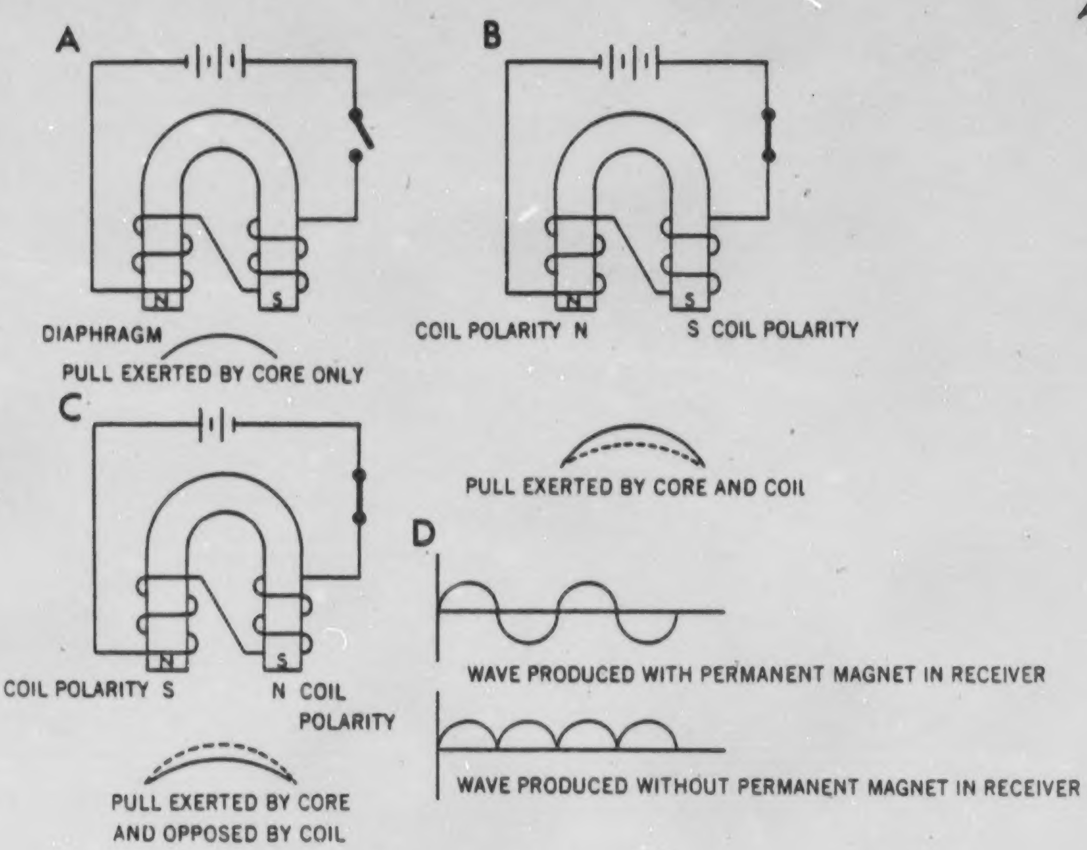
A
N
S
DIAPHRAGM
PULL EXERTED BY CORE ONLY
B
N
S
COIL POLARITY N
S COIL POLARITY
PULL EXERTED BY CORE AND COIL
C
N
S
COIL POLARITY S
N COIL POLARITY
PULL EXERTED BY CORE AND OPPOSED BY COIL
D
WAVE PRODUCED WITH PERMANENT MAGNET IN RECEIVER
WAVE PRODUCED WITHOUT PERMANENT MAGNET IN RECEIVER

Figure 5. Receiver function.

position of the coil within the magnet. Note the screws which attach the conductors to the receiver terminal plate. The other components should now be familiar to you.

1-18. **Induction Coils.** The principle of induction coils was discussed and illustrated in Volume 1 of this course. The induction coil is used in the modern telephone mainly for the following purposes:

a. To provide good transmission and reception.

b. To reduce and control sidetone during transmission.

1-19. As mentioned in Volume 1, the early telephone induction coil used two windings, a primary, and a secondary. The later induction coil, however, uses a balancing winding in addition to the primary and secondary windings. These windings will be discussed in more detail later in this chapter. They have been mentioned here for the purpose of introducing telephone parts. Before we continue with the next part (capacitors), it should be mentioned that most of the later telephones use a network assembly which contains the induction coil, capacitors, resistors, etc., which are required for transmitting and receiving.

1-20. **Capacitors.** Capacitors used in telephones have various functions. Some of these functions are listed below:

a. In the modern common-battery telephone a capacitor is connected in series with the ringer to block the passage of dc current.

b. In many telephones a capacitor blocks the passage of dc current through the receiver.

c. Capacitors with the required rating may be used in telephones to pass ringing currents and to reject voice frequencies.

d. A capacitor, used in conjunction with an induction coil, helps to produce a strong transmitter output and aids in the reduction of sidetone.

2. Comparison of Local-Battery and Common-Battery Systems

2-1. Shortly after local-battery telephone systems proved successful, telephone engineers realized that a central source of power could furnish

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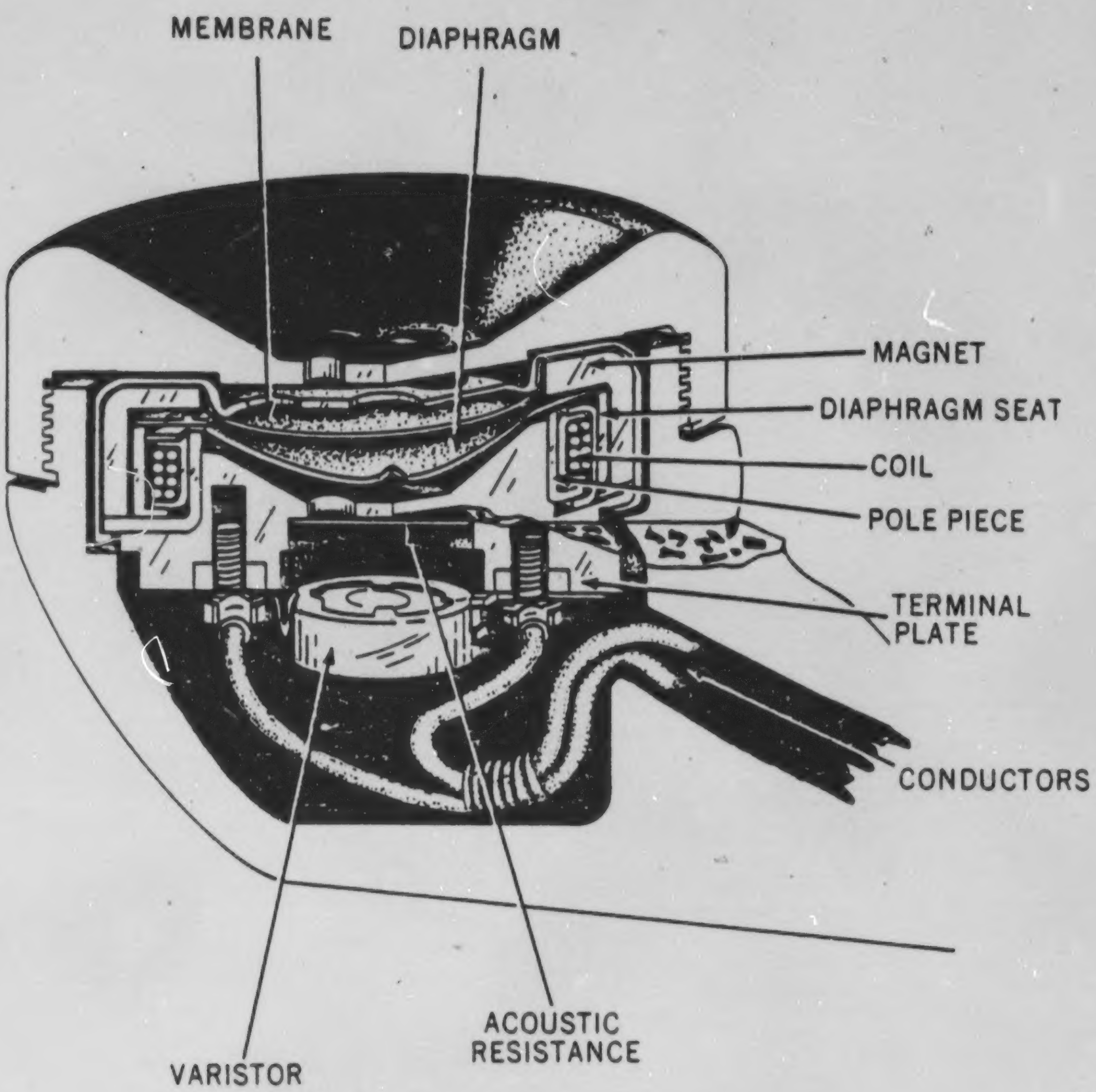

Figure 6. Modern receiver unit.

more economical and more satisfactory service. Therefore, the telephone battery was taken out of the subscriber's telephone set and installed at the central office. Although the principles of common-battery systems are similar to those of local-battery systems, the components are slightly different and are arranged in a different manner.

2-2. Before we discuss the components and their arrangement, let's briefly consider the overall arrangement of a telephone system. Look at figure 7, which illustrates a simple telephone system. Although common-battery telephones are used in this system, a similar arrangement is used with local-battery telephones. The most simple system would consist of two local-battery telephones and their connecting conductors or lines. But in all modern systems you will find a central office with either switchboards or switching equipment of some kind.

2-3. The central office and switchboard operator are often called "central" or "operator." As few as three or as many as several hundred telephone stations may be connected by lines to a single central office. The size and extent of the system may vary, but each of the telephones in a system can contact the other stations in the system.

2-4. The telephone stations, central office, and connecting lines shown in figure 7 constitute a

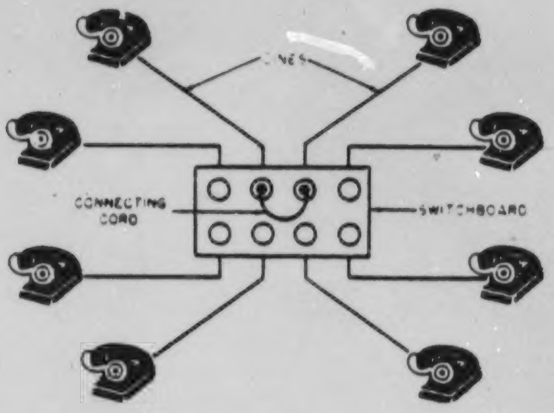

Figure 7. Telephone system.

telephone system with a single central office. Such a telephone network with its central office and connected telephone stations may be the whole system; however, it is frequently only a part of the system and is called a telephone exchange. The connection of two exchanges (as shown in fig. 8) or several exchanges by trunklines is a common arrangement. For example, a large city normally has several exchanges, all connected by trunklines.

2-5. At this point let us review the arrangement of local-battery systems and compare it with that of common-battery systems. Keep in mind that local-battery systems have all the necessary communication parts within the telephone set. Telephones in the local-battery system are operated by dry cell batteries within the individual substations, whereas those in the common-battery system have a centrally located battery. The seven major components of the local-battery phone are the receiver, transmitter, battery, induction coil, switch, hand generator, and the ringer.

2-6. In local-battery systems the sources of electrical energy for the transmitters and signaling devices are always included in each set. Thus the term "local" means that the sources of electrical energy are a part of the individual telephone. A local battery supplies the current for the transmitter circuit; a hand generator or magneto supplies the current for signaling. With this type of system, a local battery is provided not only for each subset (telephone station) but also for the switchboard.

2-7. **Components of Common-Battery Systems.** The components of the common-battery telephone are simpler than those of the local-battery subsets, because the hand generator and the battery have been eliminated at the substation. The other components of the common-battery subset—the receiver, transmitter, induction coil, ringer and hookswitch—are all similar to those found in the local-battery subset. In addition to these five components, the common-battery subset requires a capacitor in series with the ringer. The capacitor, which blocks direct current, prevents the current on the line from flowing through the ringer when the subset is not in use. If such a current were permitted, it would be a constant drain on the power supply.

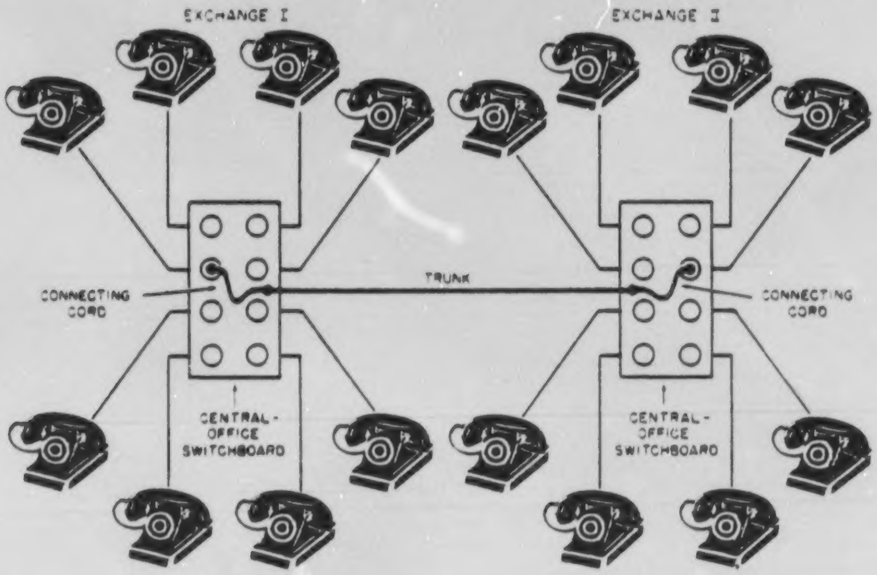

Figure 8. Two-exchange system.

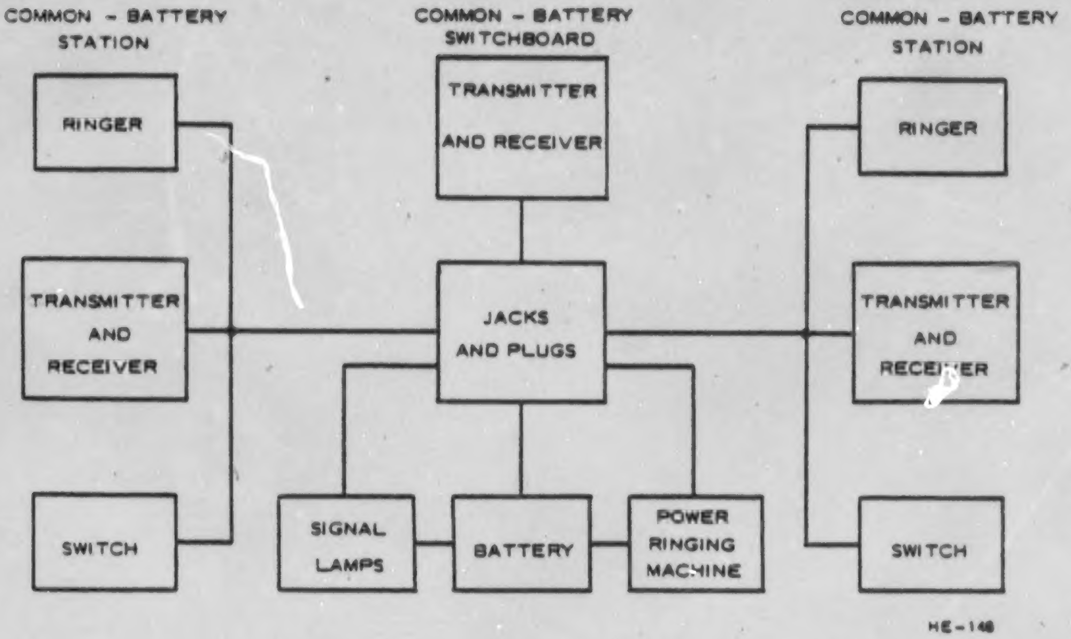

Figure 9. Common-battery system (block diagram).

2-8. Figure 9 is a block diagram of the common-battery telephone system. Since the sources of electrical energy for the transmitters and signaling devices are located at the central office, all of the stations receive their energy from a common source. This common source of power (which usually includes a generator and a large storage battery) also supplies the current for switchboard operations, including signaling lamps, a ringing machine to supply ringing current for all telephone sets, and switchboard transmissions.

2-9. The telephone stations in figure 9 have no battery; the switchboard signal lamps operate automatically when the subset receiver is removed from the hookswitch. This refinement, along with others, allows the common-battery switchboard to handle a large volume of traffic. Such operating speed and efficiency would not be possible with a local-battery system.

2-10. The operating qualities of common-battery and local-battery systems are similar. Excellent communication can be attained with either system when it is used in its proper place. Each telephone system, therefore, performs an important communications function for the armed services.

2-11. In general, military field telephone systems are manually operated and may be either the local-battery or the common-battery type. The local-battery system is used more often than the common-battery system for temporary service. Where time is a factor and the system may later be improved (or removed), a local-battery system may be installed. Field wire lines can be used with it, since they can be installed and used under somewhat adverse conditions.

2-12. **Common-Battery Advantages.** The use of common-battery systems for permanent installations reduces battery costs and increases battery efficiency. Recharging batteries costs far less than buying new dry-cell batteries, and recharging is possible because the battery is at a central location. The storage battery of the common-battery system is more efficient than the dry-cell battery. (Too, the storage battery voltage is stable.)

2-13. In manual common-battery systems the telephone user signals the switchboard simply by removing the receiver or handset from the hookswitch. This action completes the circuit for the direct current and causes the lamp on the switchboard to light. At the end of the call, the operator is again signaled by the lamp when the receiver is replaced on the hookswitch. Thus one operator can handle many more lines than would be possible otherwise. With this system no magneto at the subset is required, the subset equipment can be smaller, and the subscriber can use the subset with less difficulty.

3. Common-Battery Telephone Circuits

3-1. Figure 10 illustrates a common-battery telephone circuit. This circuit is representative of many telephones that are still in use. Of course,

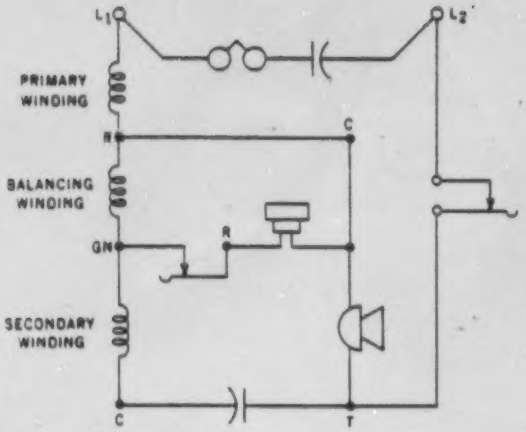

Figure 10. Antisidetone circuit schematic.

most of those still in use are equipped with a dial which is not shown in this illustration. The dial circuitry will be explained in Chapter 2 of this volume; therefore, it is not illustrated in this chapter.

3-2. Now let's discuss the telephone circuit illustrated in figure 10. Note that the circuitry is built around a three-winding induction coil. The windings of this coil are called the primary winding, the secondary winding, and the balancing winding. The balancing winding is sometimes called the tertiary winding, but don't let this fool you; it still functions in the same manner as a balancing winding. Also note that the hookswitch in figure 10 is shown with two pairs of contacts—one pair located between terminals L2 and T and the other pair located between terminals GN and R. Furthermore, the hookswitch contacts are shown in the closed position; the position they assume when the handset is removed from its cradle. One more thing, note that the ringer with its capacitor is connected between terminals L1 and L2. Thus it is in position for receiving ringing current via the telephone line.

3-3. The circuitry shown in figure 10 is of the antisidetone variety. That is, it illustrates the circuitry of an antisidetone subset (telephone) and in its simplified form, shows each portion of an antisidetone subset. The arrangement of the diagram shows that the current in one of the induction coil windings is opposite in direction to the currents in the other two windings.

3-4. The antisidetone effect is obtained by the combination of subset parts, but the heart of the antisidetone circuit is in the particular induction coil used in the telephone. The antisidetone circuit will be explained in Chapter 2.

3-5. This completes our discussion on the common battery telephone circuits. The next chapter covers station equipment for automatic systems (dial telephones). Before you study the next chapter, turn to the workbook and complete the review exercises for this chapter.

CHAPTER 2

Station Equipment in Automatic Systems

TO INSTALL and maintain telephone equipment used by the Air Force the telephone equipment installer-repairman must be familiar with both manual and automatic systems. Although most of the telephone systems used in the Air Force today are of the automatic (dial) type, you should understand both systems. You must be familiar with the transmitting, receiving, and signaling circuits, and you must understand telephone dials and dial circuits.

2. In this chapter we will discuss the telephone equipment used with automatic telephone systems, first showing how central office equipment makes a telephone call possible. In doing this, we shall see how the common-battery systems operate. We have divided the chapter into the following sections: Common-battery systems, the dial telephone, the touch tone telephone, control of switching equipment, telephone dial construction, operation, and wiring, and the 500-type telephone.

4. Common-Battery Systems

4-1. Modern telephone systems are nearly all of the common-battery type. The electrical power used in operating the telephones in most systems is supplied from the central office. When the switching and connecting of stations is done by operators in the central office, the system is then of the manual common-battery type. When the switching is done automatically in the central office and controlled by a dial on each telephone, the system is then of the dial common-battery type.

4-2. The connections between telephones in a dial telephone system are made by switching mechanisms in the central office. These mechanisms are remotely controlled by the dial on the calling telephone and do not require the aid of an operator.

4-3. In addition to some relatively new electronic switching systems, there are four electro-mechanical types of dial telephone systems used by the Air Force. These systems are as follows:

a. Step-by-step system.
b. XY system.
c. Crossbar system.
d. All-relay system.

4-4. These four dial systems interconnect the telephones of subscribers in basically the same way. The principal difference in the systems is in the equipment used. Let's briefly consider these systems.

4-5. **Step-By-Step System.** One of the most commonly used dial systems has step-by-step switches which operate directly from dial pulses transmitted from the pulse-sending device (dial) on the telephone. Operation of the dial interrupts the line current by alternately opening and closing the dial pulse contacts. In a step-by-step dial system each set of dial pulses (sometimes called train impulses or pulse trains) corresponds to the digit dialed by the telephone user. This pulse train extends a connection one step at a time (step-by-step) through the switching equipment to the called telephone. The wipers (or contacting arms of numerical, dial-controlled stepping switches) make the proper connections at the central office. Electromagnets which are operated by pulses from the dial on the calling telephone move the wipers one step at a time. Figure 11 shows how the wipers are arranged, and figure 12 shows the completed connection.

4-6. The operation of a step-by-step dial system is essentially the same as that of the manual system. For example, when the receiver is removed from the hookswitch in the manual system, the operator responds by connecting an answer cord to the calling line; that is, the operator finds the calling line with the answer cord. When the receiver is removed at a station in the dial system, a line-finder switch automatically finds the calling line and extends that line to a connector switch, which connects a tone (dial tone) to the line. The dial tone has the same significance in the dial system as the operator's "number, please" in the manual system. Then the calling party, instead of giving the desired

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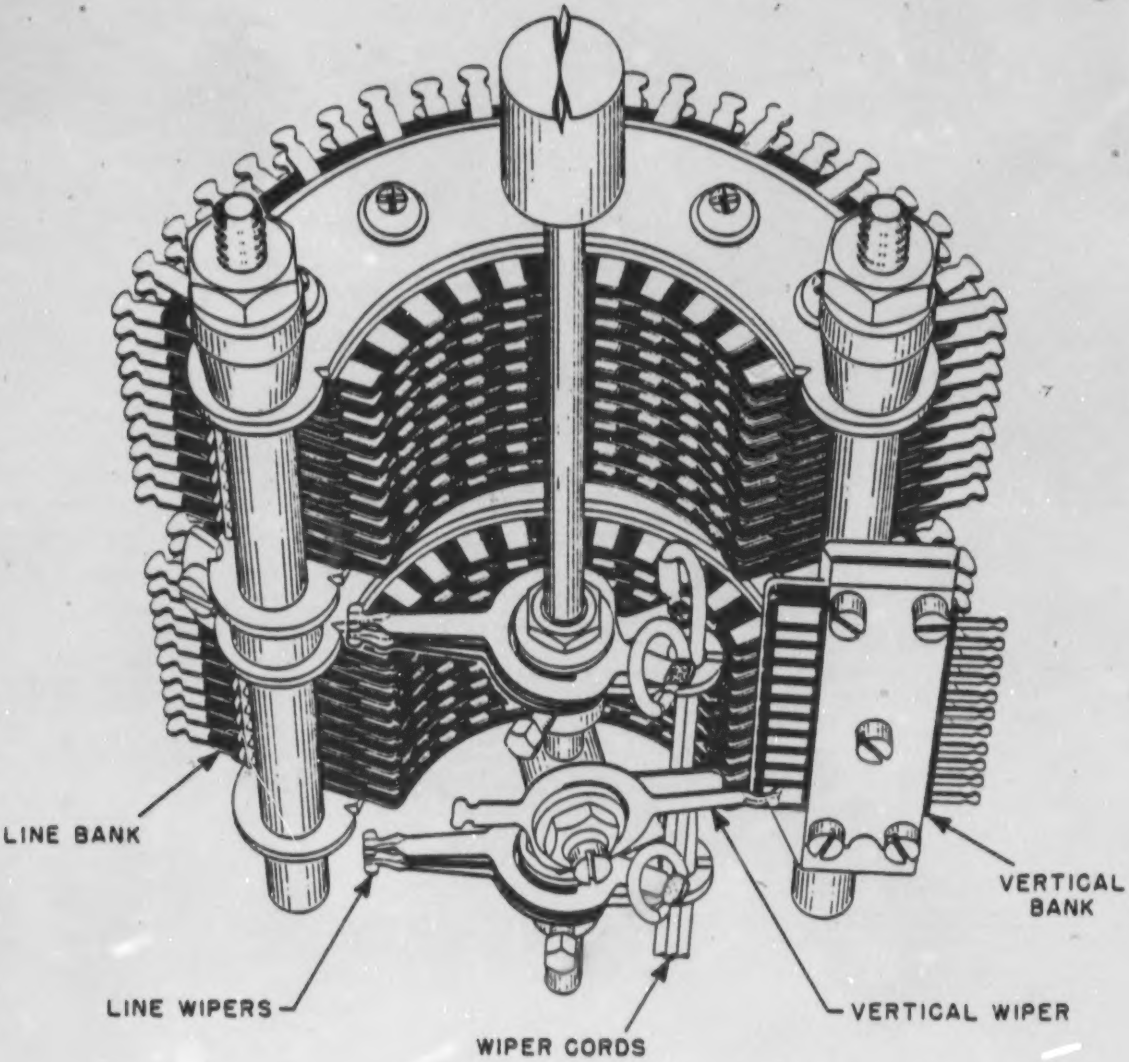


Figure 11. Switching equipment wipers and terminal bank.

number verbally, dials each digit of the line number. When the number is dialed, the connector completes the connection and automatically applies ringing current to the called line. In the manual system the operator connects the calling cord to the desired line and connects ringing current. In both systems, however, battery current must be connected to the called line. This connection is made automatically in the dial system and in the manual system when the operator releases the manually operated ringing switch.

4-7. In figures 11 and 12 you can see that each terminal bank of the switch has 10 rows of terminals with 10 terminals per row. These rows are numbered from the bottom to the top with the numbers 1 through 0, the 0 taking the place of 10. Also, the terminals in each row are numbered from left to right with the numbers 1 through 0. These row and terminal numbers combine to form a number for each terminal in the bank. For example, the telephone shown in the upper left corner of figure 12 is connected to terminal 91. The number 91 indicates that the phone is connected to the 1st terminal in the 9th row. As another example, the telephone shown in the lower right corner of figure 12 is connected to the 0 terminal in the 2d row; thus its number is 20. When a switch (such as the connector switch shown in figure 12) is dialed by the calling telephone, the wiper moves upward in response to the first digit dialed and

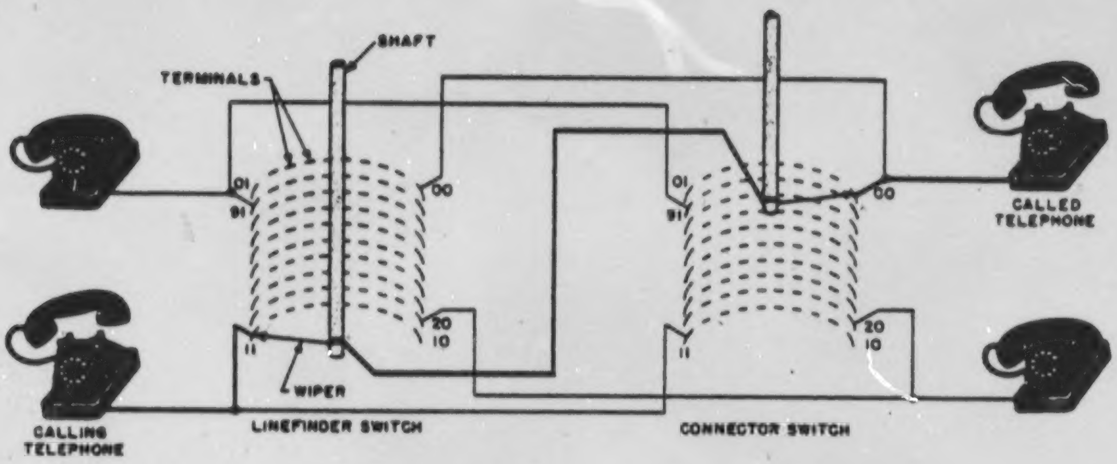


Figure 12. Simplified dial system.

then to the right in response to the second digit. Thus the dialing of 00 into the connector switch (figure 12) would place the wiper in the position shown.

4-8. **XY System.** The XY system is similar in operation to the step-by-step system. The main difference between these systems is in the type of stepping switches used. With the step-by-step system the switch operates in an upright position with the wipers stepping first in the vertical direction and then in the horizontal direction. With the XY system the switch wipers step in two directions on the horizontal plane. First, the switch is stepped in the X direction (the direction designated as east on a map) and then in the Y direction (the direction designated as north on a map). The XY switch has 10 rows of bank contacts with 10 pairs of contacts per row. Thus by stepping in two directions the XY switch can make a chosen connection out of a group of 100 possible connections.

4-9. The stepping of the XY switch in both the X and Y directions is controlled by electrical impulses generated by the dial on the subscriber's telephone. For example, if the subscriber should dial the number 48, the switch would first take 4 steps in the X direction and then 8 steps in the Y direction.

4-10. **Crossbar System.** The crossbar switch is the basic component of the crossbar system. The fundamental crossbar design has horizontal strips crossing vertical strips at right angles. Contacts placed at the intersection of these strips establish a connection. A magnetic impulse counter, which is fundamentally a relay with ten 2-step armatures, is used to store, to time, and to properly sequence the crossbar system.

4-11. **All-Relay System.** The all-relay system has groups of relays which progressively step the call. Operating alone, in response to current pulses from the calling telephone dial, these relays make the telephone connection from a calling telephone to any called telephone in the system. Instead of the electromechanical switches, such as those used in the step-by-step system, the all-relay system has electro-magnetic switches.

4-12. Without proper telephone connections and operation, of course, automatic systems will not function. The telephones which control the central office switching equipment are therefore very important.

5. The Dial Telephone

5-1. The dial telephone set consists of parts necessary for the reception and transmission of speech, for signaling, and for controlling the central office switching equipment. Part A of figure 13 shows the circuits of a typical dial telephone used with dial central offices.

5-2. Refer to part A of figure 13 and notice that the cradle switch of the dial telephone set is in the talking position. That is, the handset is off the cradle switch, permitting the switch to close the loop of the calling telephone. The dial pulse springs are shown in their normal closed position. Their purpose is to open and close the calling line loop each time the dial returns to normal. When the pulse springs open, they interrupt the direct current flowing through the loop. Part B shows this loop (pulsing circuit). The resulting pulses, or interruptions in the current of the calling line loop, operate the switching equipment in the central office to extend connections from the calling telephone to the called telephone. The dial pulse springs open and close (break and make contact) as many times as the number dialed indicates, with the exception of the digit 0

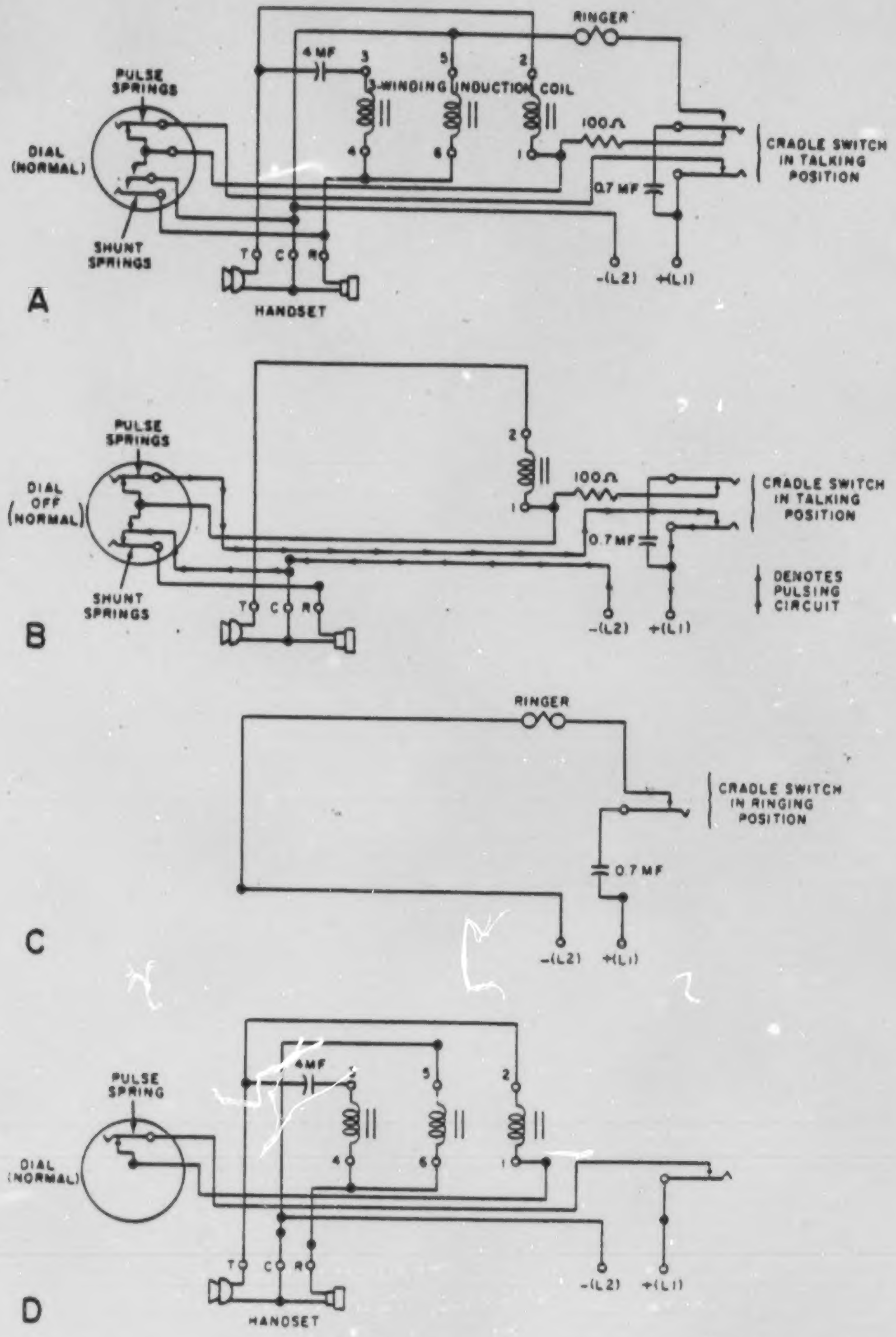

RINGER
4 MF
3
5
2
3-WINDING INDUCTION COIL
PULSE SPRINGS
100Ω
DIAL (NORMAL)
4
6
1
CRADLE SWITCH IN TALKING POSITION
0.7 MF
SHUNT SPRINGS
T
C
R
-(L2)
+(L1)
A
HANDSET
PULSE SPRINGS
2
DIAL OFF (NORMAL)
100Ω
CRADLE SWITCH IN TALKING POSITION
1
0.7 MF
DENOTES PULSING CIRCUIT
SHUNT SPRINGS
T
C
R
-(L2)
+(L1)
B
RINGER
CRADLE SWITCH IN RINGING POSITION
0.7 MF
C
-(L2)
+(L1)
4MF
3
5
2
PULSE SPRING
DIAL (NORMAL)
4
6
1
T
C
R
-(L2)
+(L1)
D
HANDSET

Figure 13. Typical dial telephone circuit.

which is an abbreviation for 10; that is, the dial pulse springs open and close 10 times in response to the dialing of digit 0. If the digit 5 is dialed, the pulse springs open and close 5 times in quick succession.

5-3. The shunt springs of the dial are shown in their initial open position because the dial in part A of figure 13 is not operated. When the dial is in the off-normal or rotated position (see part B of fig. 13), the shunt springs close and shunt out the receiver and transmitter so that they will not interfere with the pulses transmitted by the dial over the loop of the calling telephone. Shunting of the receiver during dialing prevents the dial pulses from causing clicking sounds in the receiver. Shunting of the transmitter improves the pulsing circuit by disconnecting the variable resistance of the transmitter during dialing. The shunts on the receiver and transmitter are removed when the springs return to their normal open position each time the dial comes to rest in its normal position.

5-4. The ringing circuit in part C of figure 13 consists of the springs of the unoperated cradle switch, the ringer (bell), and the 0.7-microfarad capacitor. During ringing, the capacitor permits alternating (ringing) current to flow through the telephone but blocks the flow of direct current. When the handset is lifted from the cradle switch, the capacitor and ringer are disconnected from a path directly across the loop of the telephone and the capacitor is connected to the dial pulse springs to serve as a spark suppressor (to prevent excessive sparking or arcing at the contacts of the pulse springs). The 4-microfarad capacitor in the talking circuit (part D of fig. 13) improves the transmission efficiency of the telephone. The three-winding induction coil (wound on a laminated iron core) performs three functions:

a. Couples the receiver and transmitter to the loop of the telephone.

b. Increases the efficiency of transmission by boosting the voice frequency currents developed by the transmitter.

c. Minimizes sidetone. Sidetone is the sound of one's own voice in the receiver of a telephone.

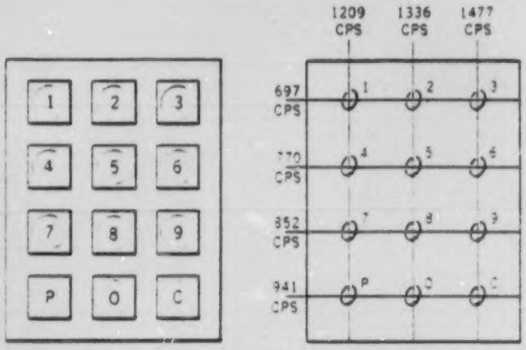
5-5. The talking circuit consists of a transmitter, a receiver, an induction coil, a 4-microfarad capacitor, and the dial impulse springs. These circuit components are used for both the transmission and reception of speech.

6. The Touch-Tone Telephone

6-1. Since manufacturers often desire different identifying terms for the equipment they develop, you will find that the same function in telephone systems is accomplished by two equipment units which have different names. To illustrate, a dual-tone multifrequency (DTMF) key set does the same job as a touch-tone multifrequency (TTMF) subset. The key set may have more buttons and be used with a different system, but your depression of the pushbuttons produces the same results.

6-2. A touch-tone dial keyboard is illustrated in figure 14A. Although it has 12 pushbuttons, there are subscriber sets with 10 and 16 pushbuttons. The pushbuttons identified as P and C are used for special service signaling. For example, a conference connection between several stations could be made while using the C pushbutton. This type subscriber set has an oscillator which has several tapped terminals. (Another set may have a number of small solid state oscillators.) Figure 14B, identifies the TONE MATRIX. Depression of each touch-tone pushbutton causes two tones to be connected to the telephone line. To illustrate, each pushbutton in figure 14B, is represented by a circle and a digit. A depressed 7 pushbutton connects the tones 852 and 1209 to the line. Figure 14B, shows the low frequency (852) at a horizontal line and the high frequency (1209) at a vertical line. Using this arrangement, what frequencies are placed on the line when you press the touch-tone pushbutton 0? Yes, the low-frequency 941 and the high-frequency 1336 tones are connected to the line! The calling subscriber will hear these tones. In time he will recognize the fact that he has made a good or bad selection by listening to the tones.

6-3. Telephone systems must be compatible. That is, each system must be able to operate with all other telephone systems. The specialized telephone equipment likewise must function in this manner. To make this performance possible,



TTMF KEYBOARD

TTMF TONE MATRIX

Figure 14. Drawing showing touch-tone keyset key arrangement.

equipment has been developed for use with stepping and crossbar systems. This equipment must accept signals from two-way circuits and transform them to pulses that are usable in the regular telephone switching equipment. Similarly, signals from a rotary dial and a single pair must be usable in the switching center.

6-4. A lifted handset may do several things. You may see it operate a relay in the line equipment of the switching center. This is the normal response in a regular switching center. In the specialized equipment system, a receiver (electronic unit) is operated. As a result, dial tone is returned to the calling subscriber. This dial tone is provided by the selector of the telephone switching equipment or by the receiver of an associate electronic unit. Also the lifted handset may signal an operator at a switchboard. You can see, then, that the equipment that responds is determined by the system installed.

6-5. You know that following your reception of dial tone, you dial the selected number. The operated rotary dial pulses the dialing relays of the selector and the connector in a regular telephone system. The same relays can be affected when electronic equipment changes TTMF originated tones to pulses. In this case the tones operate a device in the electronic equipment which, in turn, sends pulses to the incoming selector.

6-6. In another arrangement the electronic equipment unit at the switching center accepts the two tones from a DTMF key set and either sends them in that form to a second electronic unit or transforms them to logic information for further use in the electronic equipment. NOTE: Logic information for our purposes refers to a second type of electronic signal. Following arrival of the tones at the electronic switching equipment and their transformation in this equipment, pulses are sent to the succeeding electronic equipment. These pulses give the same result as does the duplicate digit from a rotary dial; they pick the line of the called party.

6-7. An incoming call to a PABX is processed by the operator. The call may be forwarded as tone signaling or pulse signaling. It may be completed by an electronic telephone system or an electromechanical system. Remember, if the calling station is a rotary dial station on a two-wire line, the connection with the called two-wire station is completed with the familiar electromechanical methods. A connection to a touch-tone called station requires signal conversion for call completion.

6-8. The conversational circuit between a calling rotary dial station and a called touch-tone station requires conversion by the electronic switching equipment. Vice versa, the transmitting circuit between a calling touch-tone station and called rotary dial station also requires signal conversion. Units that provide signal conversion are referred to as "interface equipment."

6-9. All telephones permit a subscriber to actuate equipment in a switching center. Although the operation of the subset may be different, the end result is the same. We will now describe a sample operation of telephone switching equipment.

7. Control of Switching Equipment

7-1. Shown in figure 15 is a simplified schematic diagram of the subscriber's dial and its relationship to the central office equipment. You will understand how it operates when you have read the following paragraphs discussing seizure, dialing, and release.

7-2. **Seizure.** When the subscriber removes his handset from the cradle of the telephone, the hookswitch operates and completes a path for current which extends from ground through the upper winding of relay A, the hookswitch, the pulse springs, and back through the lower winding of relay A to the battery and ground. Relay A operates to close its make contacts and complete a path for current through the winding of relay B and the make contacts of relay A to ground. Relay B operates to prepare an operating path for the magnets. The path to the magnets is open at the break contacts of relay A.

7-3. **Dialing.** The subscriber pulls the finger plate around to the finger stop. If he places his finger in the finger plate hole above the numeral 2 and pulls the plate around to the finger stop, then when the finger plate is released there are 2 pulses, or interruptions, of current in the operating circuit of relay A. These pulses of current are listed below as break and make. Break and make state the condition of the dial pulse springs. The break condition exists when the pulse springs are open, permitting no current through relay A, which causes it to release. In the make condition the pulse springs are closed; this lets current through the relay A circuit and causes it to operate.

7-4. As the subscriber dials the numeral 2, the following sequence of events takes place:

a. 1st Break

(1) *Relay A releases.*

(a) Opens the circuit to relay B. Relay B does not release during pulsing as it is a slow-to-release relay.)

(b) Closes the operating circuit to the magnets.

(2) *Magnets operate.* (Magnet operation causes a step-by-step or XY switch to move its wipers one step.)

b. 1st Make
  (1) *Relay A reoperates.*
  (a) Opens the circuit to the magnets.
  (b) Closes the circuit to relay B.
  (2) *Magnets release.*

c. 2d Break
  (1) *Relay A releases.*
  (*a*) Opens the circuit to relay B.
  (*b*) Closes the circuit again to the magnets.
  (2) *Magnets reoperate.* (Steps the switch one more step.)

d. 2d Make
  (1) *Relay A reoperates.*
  (a) Opens the circuit to the magnets.
  (*b*) Closes the circuit to relay B.
  (2) *Magnets release.*

7-5. When the subscriber dials a larger number, there are more breaks and makes, operating and releasing the magnets more times. For example, if the digit dialed is 6, there are 6 breaks and makes, operating and releasing the magnets 6 times, which in turn step the switch 6 times.

7-6. **Release.** When the subscriber hangs up (places the handset on the cradle switch), the circuit of relay A is opened. Relay A releases and opens the circuit to relay B which, after a delay, also releases.

8. Telephone Dial Construction, Operation, and Wiring

8-1. The telpehone dial shown in figure 16 is a part of the telephone set. We saw that it is the unit the subscriber uses to control the central office switching equipment. It is a pulse-sending device, or circuit interrupter, operated by the calling subscriber.

8-2. **Dial Construction.** Although the dial shown in figure 16 is not of the most recent design, it illustrates the basic parts of a typical telephone dial. As shown in the illustration, the dial consists of the following basic parts: number plate, finger plate, finger stop, mounting plate, pulse cam, pulse spring assembly, shunt spring assembly, shunt cam, helical restoring spring, ratchet drive mechanism and governor assembly.

8-3. *Number plate.* The number plate contains the numerals 1 through 0. On the metropolitan dial, the letters of the alphabet are included.

8-4. *Finger plate.* The finger plate contains 10 holes equally spaced. When the dial is at normal, each hole is located over one of the numerals on the number plate. The finger plate is operated by inserting the index finger into one of the 10 holes corresponding to the digit to be dialed. Then the finger plate is pulled in a clockwise direction until the finger hits the finger stop. When the finger plate is released, spring pres-

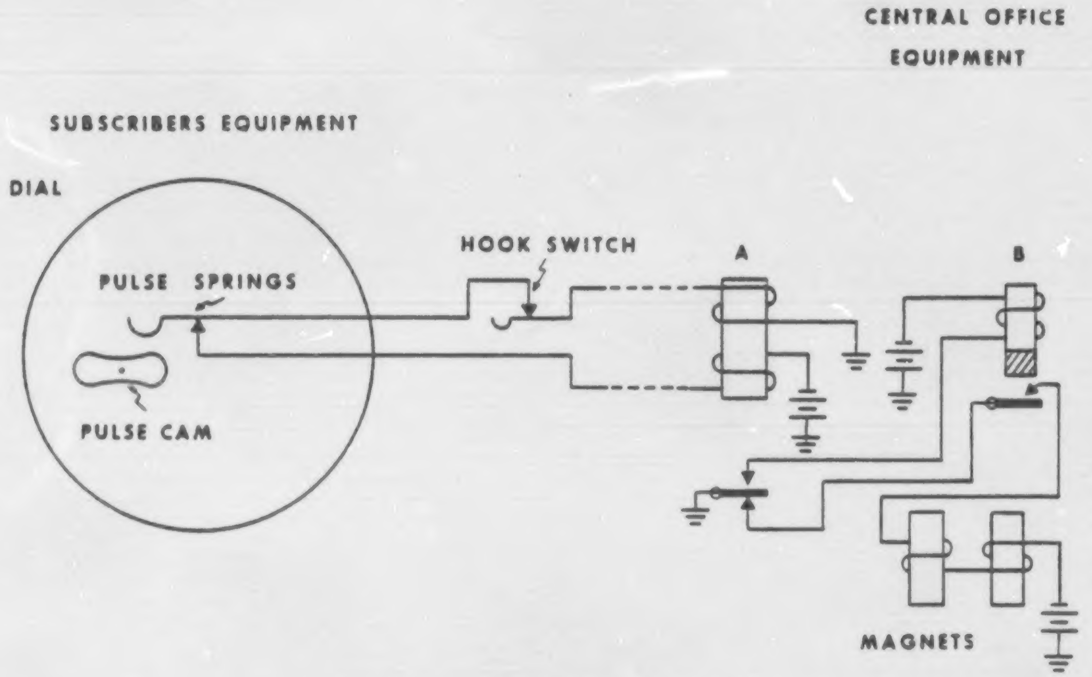


Figure 15. Simplified dial and switch circuit.

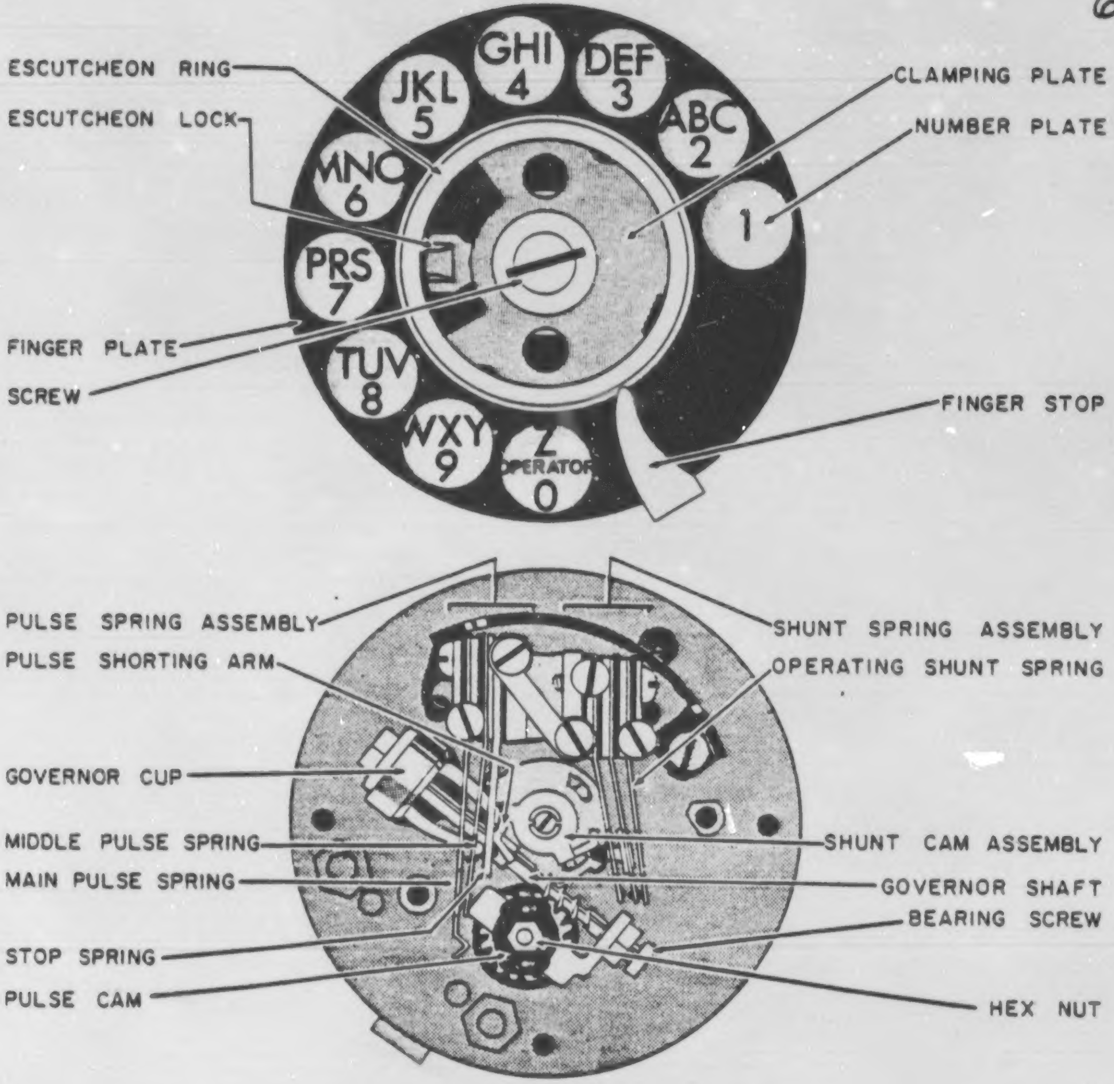

ESCUTCHEON RING
ESCUTCHEON LOCK
FINGER PLATE
SCREW
CLAMPING PLATE
NUMBER PLATE
FINGER STOP
GHI 4
DEF 3
ABC 2
1
JKL 5
MNO 6
PRS 7
TUV 8
WXY 9
Z OPERATOR 0
PULSE SPRING ASSEMBLY
PULSE SHORTING ARM
GOVERNOR CUP
MIDDLE PULSE SPRING
MAIN PULSE SPRING
STOP SPRING
PULSE CAM
SHUNT SPRING ASSEMBLY
OPERATING SHUNT SPRING
SHUNT CAM ASSEMBLY
GOVERNOR SHAFT
BEARING SCREW
HEX NUT

Figure 16. Typical telephone dial.

sure pulls it back in a counterclockwise direction and causes the pulse cam to operate and send out a number of pulses corresponding to the digit dialed. The dial card is attached to the finger plate and usually contains the telephone number of the subscriber's telephone.

8-5. *Finger stop.* The finger stop is a metal projection that extends over the surface of the finger plate to stop the finger during dialing. This insures that the movement of the finger plate is stopped at the same position every time.

8-6. *Mounting plate.* The mounting plate is a shallow metal cup to which all of the dial parts are attached. It is a means for mounting the dial to the telephone.

8-7. *Pulse cam.* The pulse cam is a two-lobed cam which actuates the main pulse spring. The cam is driven by the main drive gear as the finger plate returns to normal.

8-8. *Pulse spring assembly.* The pulse spring assembly consists of two contact springs and a back stop. The pulse springs are actuated by the pulse cam.

8-9. *Shunt spring assembly.* The shunt springs (sometimes called off-normal contacts) are placed on the dial to shunt out the receiver and transmitter during the pulsing period. The shunt springs are held open by the shunt cam when the finger plate is at normal. As soon as the finger plate is moved off normal, the shunt cam causes the contacts to close until the finger plate again returns to normal.

8-10. *Shunt cam.* The shunt cam is a two-lobed brass cam mounted on the end of the main dial shaft. One lobe of the cam actuates the shunt springs; the other lobe moves the pulse springs away from the pulse cam after the last pulse to give a time delay between the last pulse of one digit and the first pulse of the next digit.

8-11. *Helical restoring spring.* The helical restoring spring attached to the main drive gear shaft furnishes the power to operate the dial during the pulsing period.

8-12. *Ratchet drive mechanism.* The ratchet drive mechanism consists of a pawl and ratchet gear attached to the main drive gear. As the finger plate is operated, the pawl clicks over the ratchet teeth so that the pulse cam and governor remain at rest. As soon as the finger plate is released and begins to restore, the pawl engages one of the ratchet teeth and sets the dial mechanism into motion.

8-13. On later model dials using the friction type pawl silencer, the pawl is lifted away from the ratchet teeth as the dial is moved off normal and does not drop into engagement with the ratchet teeth until the finger plate is released.

8-14. *Governor assembly.* The dial governor automatically regulates the speed of the dial pulses to insure uniform response of the central office switching equipment. The pulsing speed of a properly adjusted dial is 10 pulses per second. The dial timing must be highly accurate to allow the switching equipment to function. Proper governor setting insures that the pulses are sent at the correct speed. The acceptable speed for the dial most used in todays telephone is 9 to 11 pulses per second (pps), 10 pps would be perfect.

8-15. When performing an operational check of a telephone (bench repair or trouble report) and you suspect dial trouble, you should call the test board for a dial check. The central office has the test equipment to check the speed of the dial.

8-16. **Operation.** In general the operation of all dials is similar. When the subscriber wants a number, he places his finger in the hole in the finger plate that corresponds to the digit to be dialed and then turns the plate in a clockwise direction until his finger hits the finger stop. This turning winds the dial drive spring and operates the dial shunt contacts. The dial is then ready to function. When the subscriber releases the finger plate the drive spring returns the mechanism to the unoperated position. While the mechanism is returning to this position, the pulse cam operates the pulsing springs, opening and closing the pulsing circuit the same number of times as the number of the digit dialed. As the finger plate reaches its unoperated position, the shunt contacts return to their normal position. Furthermore, as the finger plate returns to its normal position, a governor controls the return speed—thus determining the rapidity of the pulsing operation.

8-17. **Operational Differences.** Although many telephone dials are constructed differently, the pulsing springs on all dials perform in approximately the same manner. The main difference between the different types of dials is in the operation of the shunting spring contacts. To observe this difference in shunting spring operation and to further your studies of dials and dial wiring, refer to the schematic diagram in figure 17.

8-18. **Dial Wiring.** The heavy lines in this illustration indicate the path of the dial pulses. Note that when the dial contacts between springs 3 and 4 are operated, they short circuit not only the transmitter but also the primary winding of the induction coil. Short circuiting the primary winding reduces interference between the telephone and any nearby radio equipment during the dialing period; it also reduces the dialing circuit resistance. Also note that the dial contacts between springs 5 and 6 (fig. 17) open the receiver circuit when the dial is moved off normal. This is directly opposite from the circuitry shown in figure 13, where the receiver circuit is shorted by the shunt springs. In figure 17 the pulsing contacts (1 and 2) are always closed except while the dial finger plate is returning to normal. When a digit is dialed on this telephone, the pulse cam causes these contacts to open and close while the finger plate is returning to normal. The number of times that the contacts open and close corresponds to the number of the digit dialed. Thus these contacts pulse the line circuit, causing current surges that control the switching equipment at the central office.

9. The 500-Type Telephone

9-1. The subset that is most widely used throughout the United States is the commercial 500 telephone. As mentioned in Chapter 1, this telephone was adopted by the Army and Air Force as the standard telephone for both services.

9-2. Although the 500-type telephone is manufactured by most of the major telephone equipment manufacturers, there are only two such instruments in which the parts and circuits are identical. The 500-type telephones manufactured by Western Electric Company and by ITT-Kellogg are identical. They use identical parts and wiring, and all of the parts are interchangeable. When we speak of the 500 telephone, we are

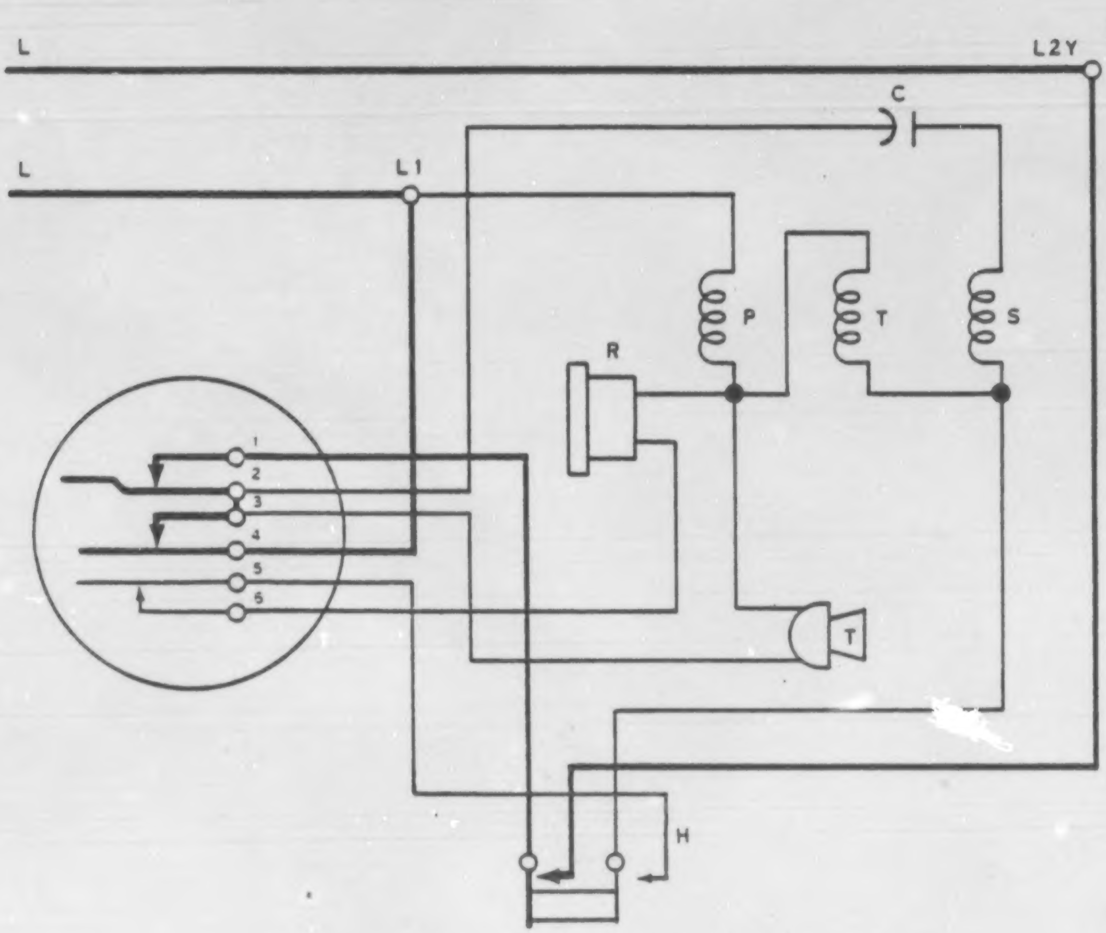

L
L2Y
C
L
L1
P
T
S
R
1
2
3
4
5
5
T
H

Figure 17. Dialing circuit schematic.

referring to the identical instruments made by these two companies. With the knowledge gained from your previous studies as well as from this part of the text, you should have no trouble in understanding the operation of any of the 500-type instruments.

9-3. The 500 telephone, illustrated in figure 18, is of the type that is commonly used at the present time. As you can see in the illustration, the part identified as the finger plate in figure 16 is called the dial wheel. You should also observe, that the dial numbers and letters are located on a plate outside the dial wheel rather than under it. To explain this telephone more thoroughly, let's first discuss its components and construction, and then its circuits and operation.

9-4. **Components.** The major components of the 500 telephone are basically the same as those described previously. They consist of a handset, a telephone housing assembly, a handset cord, and a mounting or deskstand cord. The handset is shorter than the older types—thus placing the transmitter closer to the speaker's mouth during

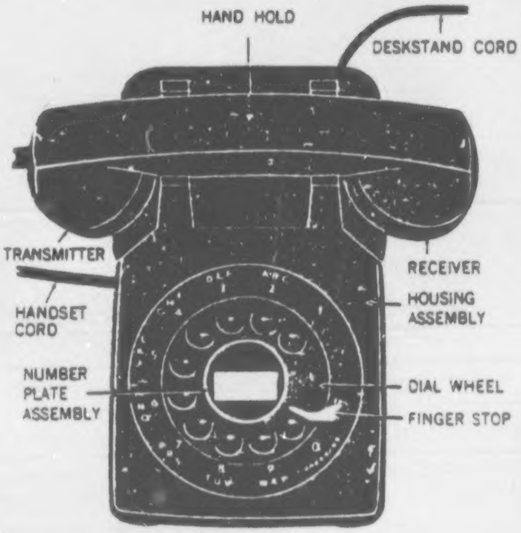

HAND HOLD
DESKSTAND CORD
TRANSMITTER
RECEIVER
HANDSET CORD
HOUSING ASSEMBLY
NUMBER PLATE ASSEMBLY
DIAL WHEEL
FINGER STOP

Figure 18. 500 type telephone.

operation. The handset cord uses four conductors, two for the transmitter and two for the receiver. Remember that the older handset cord uses three conductors; one for the receiver, one for the transmitter, and one that is common to both the transmitter and receiver.

9-5. For a telephone to operate in an automatic system, it must have the same basic parts as described previously. It must have a transmitter, a receiver, a hookswitch, a ringer, a dial, an induction coil, and a capacitor. All of these parts are necessary if the telephone is to operate satisfactorily. Although these parts are designed and arranged differently, the 500 telephone uses all of them plus some additional ones to improve its operation. To explain the parts used in this telephone, let's consider them individually.

9-6. *Transmitter.* The transmitter used with the 500 telephone is illustrated in figure 19. Although this transmitter looks like the older type of carbon transmitter, its operation has been greatly improved. One of the main improvements in this transmitter is a special treatment of the carbon granules, which provides continuously a more uniform contact and thus an improvement in the quality of transmission. Also, the carbon cup and diaphragm electrode are shaped so that the carbon granules cannot fall into a corner and pack, and the transmitter may be used in any position.

9-7. The method used in mounting this transmitter in the handset is also different from the older methods of mounting. In figure 19 you will notice a plastic cup mounted in the handset opening just below the transmitter unit. The transmitter conductors from the handset cord are connected to the lower side of the plastic cup by screw-type terminals. These terminals extend through the plastic cup to spring contacts which, in turn, are engaged with silver contacts on the lower side of the transmitter unit. Thus when the cap that holds the transmitter unit in place is unscrewed, the transmitter unit can be lifted off the spring contacts, facilitating the removal and replacement of the transmitter unit. Besides being a mounting for the transmitter unit, the plastic cup performs other important functions in the handset. First, because of its shape, it forms a controlled acoustic cavity back of the transmitting unit. Second, the cup provides an acoustic shield between the transmitter and receiver. If it were not for this acoustic shield, the sound would travel through the hollow handle of the handset from the transmitter to the receiver and vice versa, with an adverse affect on both transmission and reception.

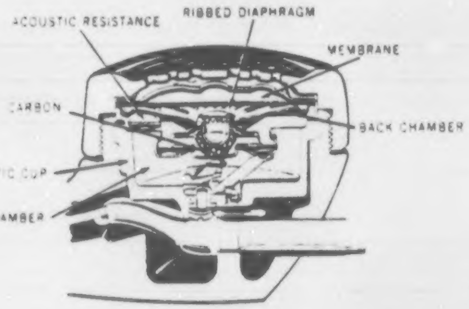


Figure 19. Transmitter for 500 telephone.

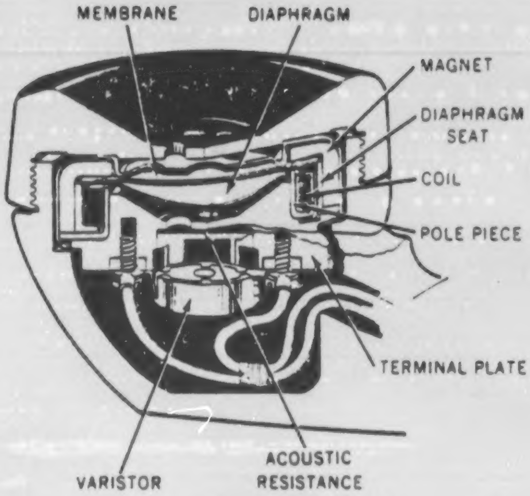


Figure 20 Receiver for 500 telephone.

9-8. *Receiver.* The receiver used with the telephone is illustrated in figure 20. Note that this receiver is constructed with a ring magnet that greatly improves its operation. Also, with its diaphragm constructed in a dome shape the receiver is much more efficient and has a greater frequency response than the older receivers. Because this receiver is so efficient, a varistor is connected across the terminals to protect the user from high acoustic levels that may be caused by stray electrical voltages entering the telephone circuit. The varistor also protects the receiver magnet from being demagnetized by such stray voltages. You should also note while looking at the illustration that the receiver conductors from the handset cord are connected to the receiver unit by terminal screws. Thus it is necessary to disconnect these terminals before you can remove the receiver unit.

9-9. *Hookswitch.* Rivets attach the hookswitch mounting bracket to the telephone base plate. The switch assembly with its protective plastic housing is attached to the mounting bracket in a manner that facilitates the operation of its contacts by a switch control lever. Operation of the switch is illustrated in figure 21. This illustration shows the contacts in two positions. In the upper part of the illustration they are in the position they assume when the handset is in place on its cradle—in the lower part of the illustration they are in the position they assume when the handset is lifted from its cradle.

9-10. In the lower part of figure 21, the contacts are identified alphabetically by the letters A through G. These letters also apply to the contacts in the upper part of figure 21. As you will see later, these letters are used in schematic drawings to identify the hookswitch contacts. In the upper part of the illustration, contacts F and G are closed to short out the receiver when the handset is in place on its cradle. Also the line to network contacts (B to C and D to E) are open when the handset is in place. Therefore, except for the ringer, the telephone components are disconnected from the line whenever the handset is on its cradle.

9-11. Now when you examine the lower portion of figure 21, you will see the position of the

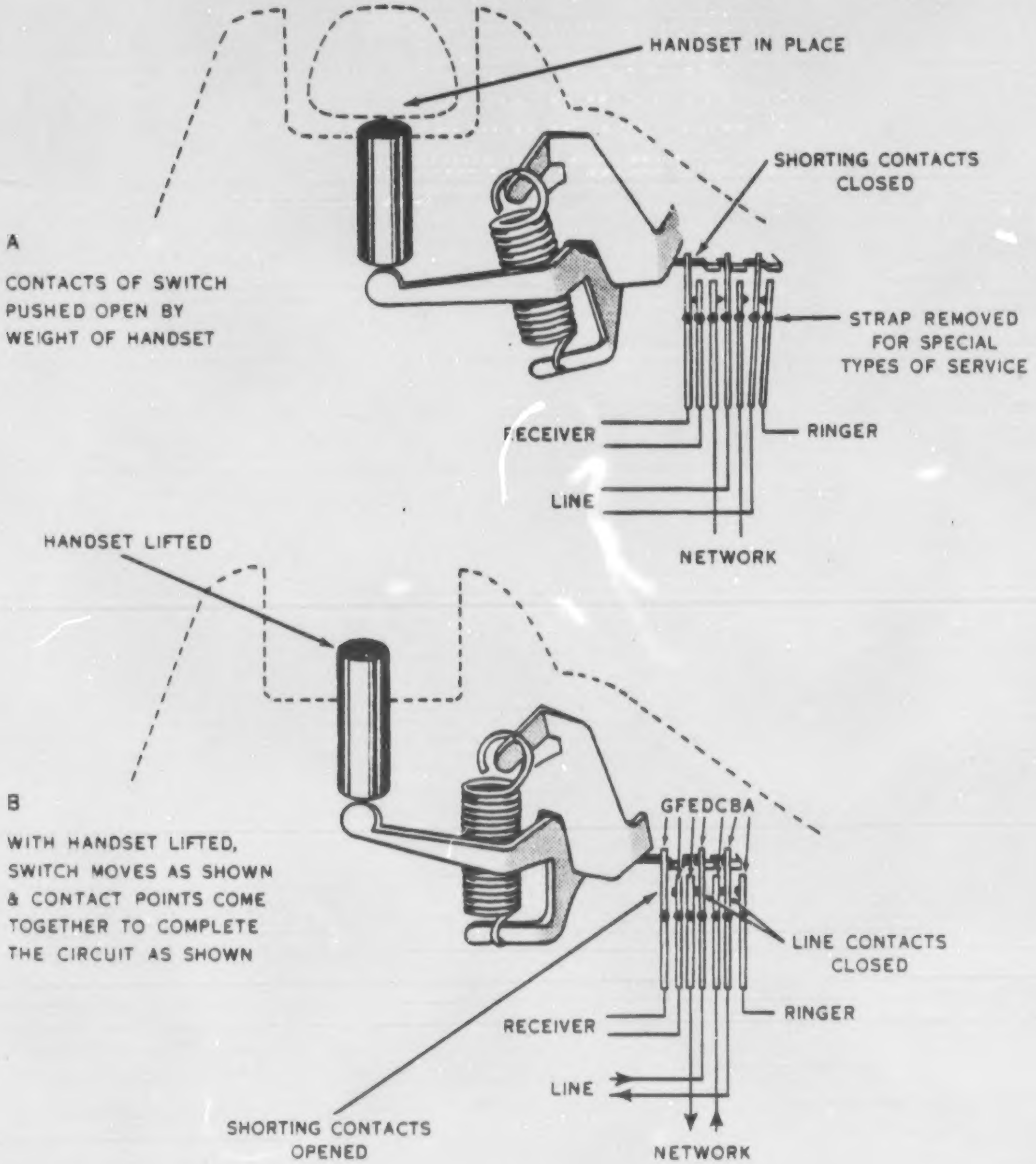

HANDSET IN PLACE
SHORTING CONTACTS CLOSED
A
CONTACTS OF SWITCH PUSHED OPEN BY WEIGHT OF HANDSET
STRAP REMOVED FOR SPECIAL TYPES OF SERVICE
RECEIVER
RINGER
LINE
NETWORK
HANDSET LIFTED
B
WITH HANDSET LIFTED, SWITCH MOVES AS SHOWN & CONTACT POINTS COME TOGETHER TO COMPLETE THE CIRCUIT AS SHOWN
GFEDCBA
LINE CONTACTS CLOSED
RECEIVER
RINGER
LINE
SHORTING CONTACTS OPENED
NETWORK

Figure 21. 500 telephone hookswitch.

contacts when the handset is removed from its cradle. In this position, the shorting contacts (F and G) are open—thus removing the short from the receiver circuit. Also, the line to network contacts (B to C and D to E) are closed to connect the line to the network and telephone circuitry. The ringer to line contacts (A to B) are open. It should be noted, however, that the ringer lead to contact A is not normally used in the ringer circuit. It is used only for special types of service.

9-12. *Ringer.* The ringer used in the telephone is illustrated in figure 22. The components of this assembly include a ringer frame, two ringer coils wound on one spool, a coil core, two permanently mounted resonator shells, two brass gongs, a biasing spring, an armature stop rod, and a ringer loudness-control arrangement.

9-13. The ringer parts are attached to the ringer frame and the entire assembly is mounted on the telephone base plate. The loudness-control feature is made accessible to the user by a knurled section on a control wheel that extends through a rectangular slot in the base plate. The entire ringer can be replaced as an assembly; or the ringer coil, coil core, and brass gongs can be replaced individually. Other than these, the ringer parts are not replaceable at any maintenance level. As you can see in figure 22, the biasing spring tension is determined by placing the spring in one of two notches on the biasing spring bracket. One notch provides high tensions and the other notch low tension. If it becomes necessary to remove and replace the ringer coil, you must use care to maintain polarity of the coil core and permanent magnet. If the permanent magnet becomes discharged, it must be remagnetized before the ringer can be used. One reason for this is that the ringer operates with two coils wound on one core to form one electromagnet. The permanent magnet must furnish magnetic force normally furnished by a second electromagnet on other ringers.

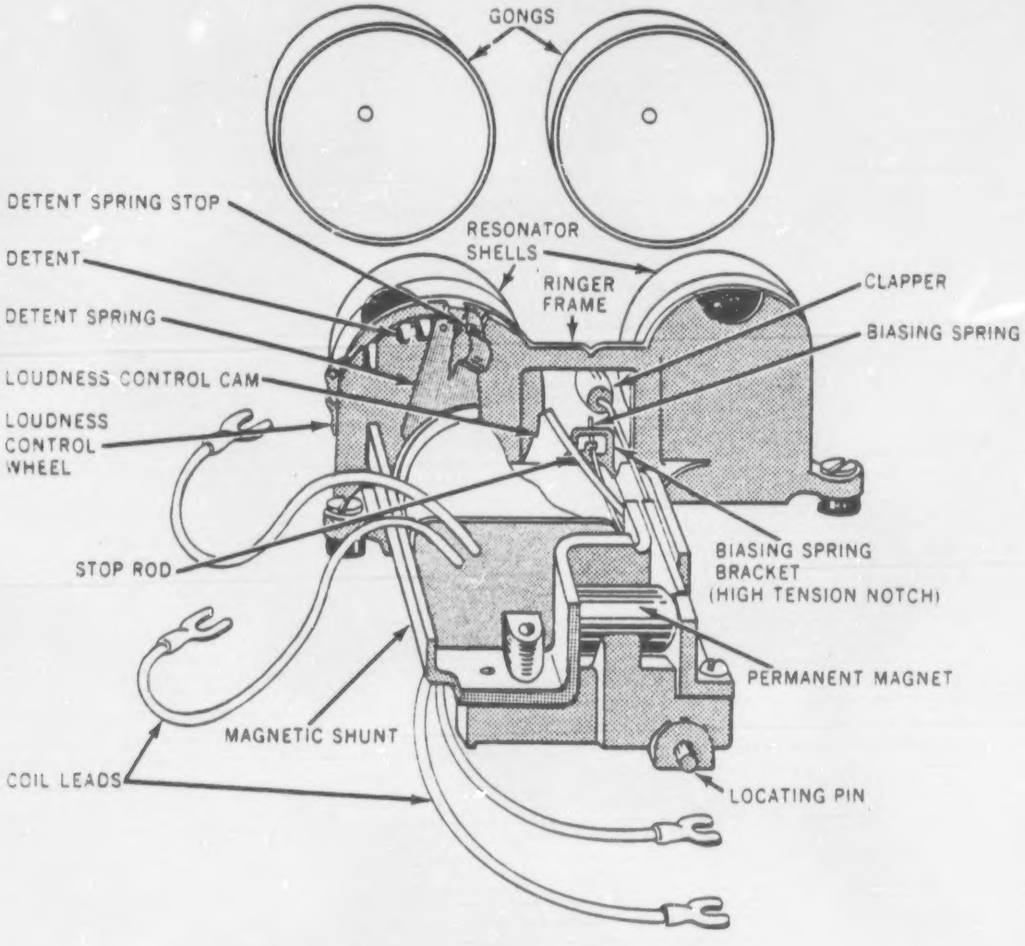

GONGS
DETENT SPRING STOP
RESONATOR SHELLS
DETENT
RINGER FRAME
CLAPPER
DETENT SPRING
BIASING SPRING
LOUDNESS CONTROL CAM
LOUDNESS CONTROL WHEEL
STOP ROD
BIASING SPRING BRACKET (HIGH TENSION NOTCH)
PERMANENT MAGNET
MAGNETIC SHUNT
COIL LEADS
LOCATING PIN

Figure 22. Ringer for the 500 telephone.

9-14. *Dial.* Figure 23 shows a rear view of the dial assembly, for the telephone. In this illustration, the protective housing has been removed to provide a better view of the parts. As you can see in the illustration, this dial has basically the same parts as those discussed previously but they are constructed and arranged differently. The dial contact springs, molded in a block of insulating material, have attached leads that are equipped with spade tips to facilitate their connection. When the telephone is assembled these dial leads are connected to screw terminals on the network terminal board. There are only two pairs of contact springs provided on this dial: one pair for pulsing, and the other pair for short-circuiting the receiver winding when the dial is in the off-normal position. You should note that while these springs are called "shunt contacts" in figure 23, they are also called the "off-normal contacts" in many diagrams and drawings.

9-15. When the dial is completely assembled, the mechanism is protected by a plastic housing that covers all the parts except the spring terminal leads. When the telephone is assembled, the dial assembly is mounted on a dial mounting bracket riveted to the telephone base plate.

9-16. *Network.* In the previous paragraphs we discussed the transmitter, receiver, hookswitch, ringer, and dial. These are only five of the seven

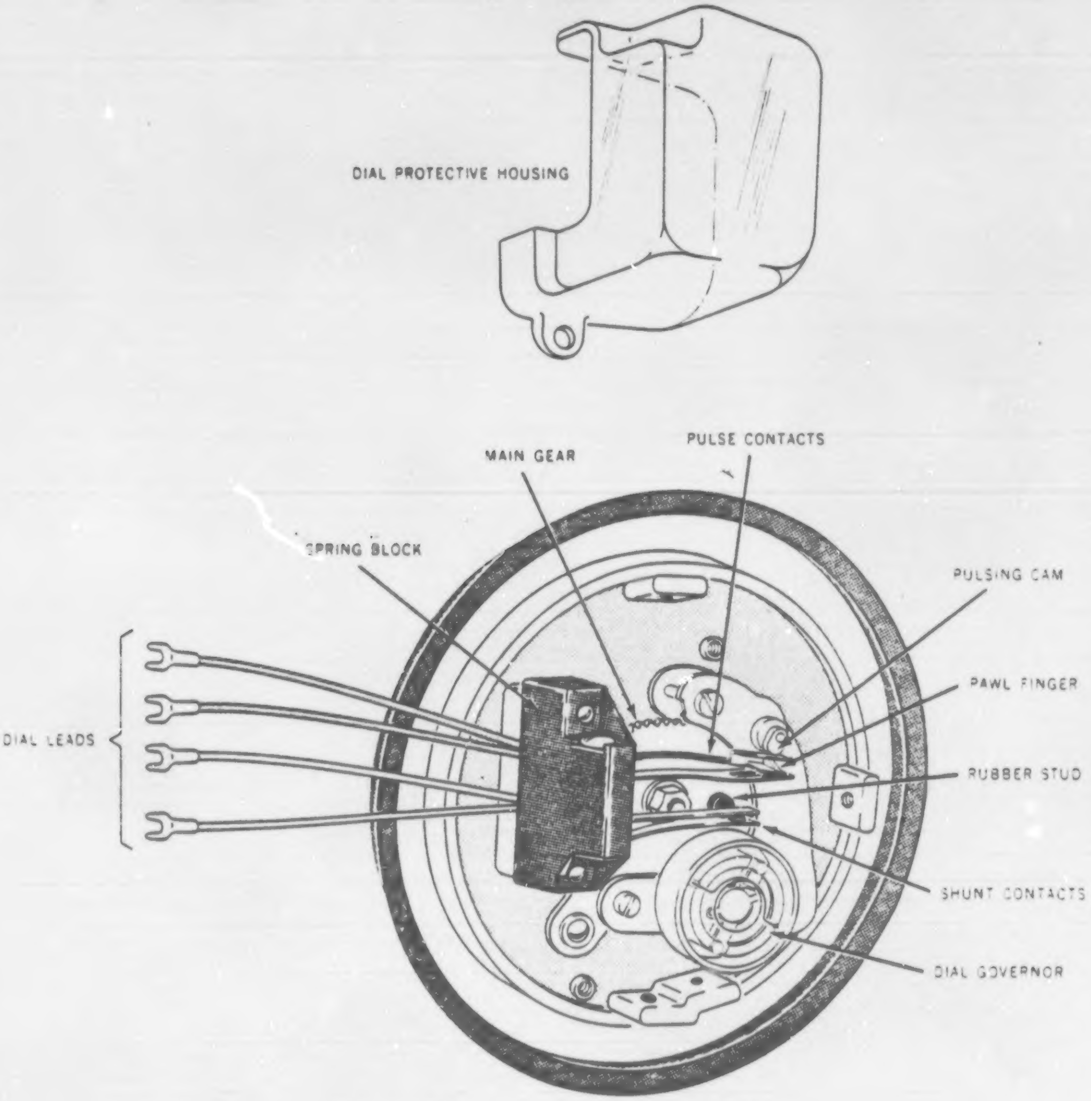


Figure 23. Dial for the 500 telephone (rear view).

components which are necessary for the operation of a modern telephone. The other two components are the induction coil and capacitor. The induction coil and capacitor, however, are sealed into a network assembly in the telephone. Therefore, we will cover these two items in our discussion of the network and circuits.

9-17. The network assembly for the telephone is shown in figure 24. Its parts are mounted in a metal container with their leads brought out to terminals on a plastic terminal board. In addition to the induction coil and ringing capacitor, there are three other capacitors, three resistors, and two varistors contained in the network assembly. In the construction of this assembly, the parts are assembled and placed in the can, and then the remaining air space in the can is filled with a moisture-proof sealing compound. This procedure seals the network so effectively that very little trouble is experienced with this part of the telephone.

9-18. As the telephone is assembled, the network is riveted to the telephone base plate. When a part of the network goes bad, it is the usual practice to replace either the network or the telephone. Normally the telephone is replaced for the customer and then the old telephone is taken to the shop where it is repaired by replacing the network assembly. It should be mentioned, however, that in some cases when the ringing capacitor goes bad, it may be corrected by installing a special capacitor on the outside of the network. To give you a better understanding of the network, we will discuss its internal circuits along with the circuits used in the 500 telephone. But before we discuss these circuits, let's briefly consider the arrangement of the telephone components and parts.

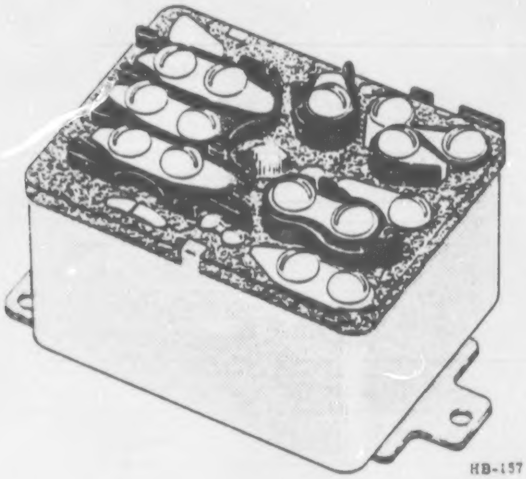


Figure 24. 500 telephone network assembly.

9-19. *Arrangement of parts on the base plate.* Figure 25 is an illustration of the telephone assembly with the housing removed. Note the location of the various parts. The dial is mounted on a bracket at the right of the illustration. The hookswitch, with its arms extended out over the other components, is mounted next to the dial. The ringer and network assemblies are also plainly visible. You can see where the handset and mounting cords are held by metal fastening devices at the edge of the telephone base plate.

9-20. **Circuits.** The circuitry of the 500 telephone may be divided into five circuits as follows: ringer circuit, transmitter circuit, receiver circuit, dial circuit, and antisidetone circuit. These circuits are all included in the wiring diagram illustrated in figure 26, which is actually a complete schematic wiring diagram for the 500 telephone. Before we discuss the five circuits, however, there are several points that should be made clear in respect to the wiring diagram. First of all, the network parts and terminals are all shown inside of a dotted line on the diagram. The terminals, with their identifying letters and numerals, are shown in the same relative positions as they appear on the network itself. For the purpose of explanation, the internal parts of the network have been identified with letteers and numerals in the illustration. For example, the primary windings of the induction coil are identified as P1 and P2; the secondary windings are identified as S1 and S2. The resistors are identified as R1, R2, and R3; the capacitors as C1, C2, C3, and C4; and the varistors as CR1 and CR2. We point this out because in many diagrams the network parts are not identified; probably because they are not replaceable as individual parts. However, when it is necessary to identify the network parts in a diagram, the identifying symbols as shown in figure 26 are normally used.

9-21. Now observe the conductors at the upper right of figure 26 identified as T and R. The T and R stand for tip and ring, as was explained in the resident course. Tip and ring, as you may recall, refer to the lines from the central office, the names coming from the parts of the jack and plug used on the manual common-battery switchboard. The ring side of the line is always connected to negative battery at the central office and the tip side is connected to positive battery and ground. Thus, in respect to the battery current furnished to the modern telephone, the ring side of the line is negative and the tip side of the line is positive. The tip side of the line is connected to ground at the central office except during the ringing period in certain types of ringing systems. (This feature will be further explained along with ringing systems in a later volume.)

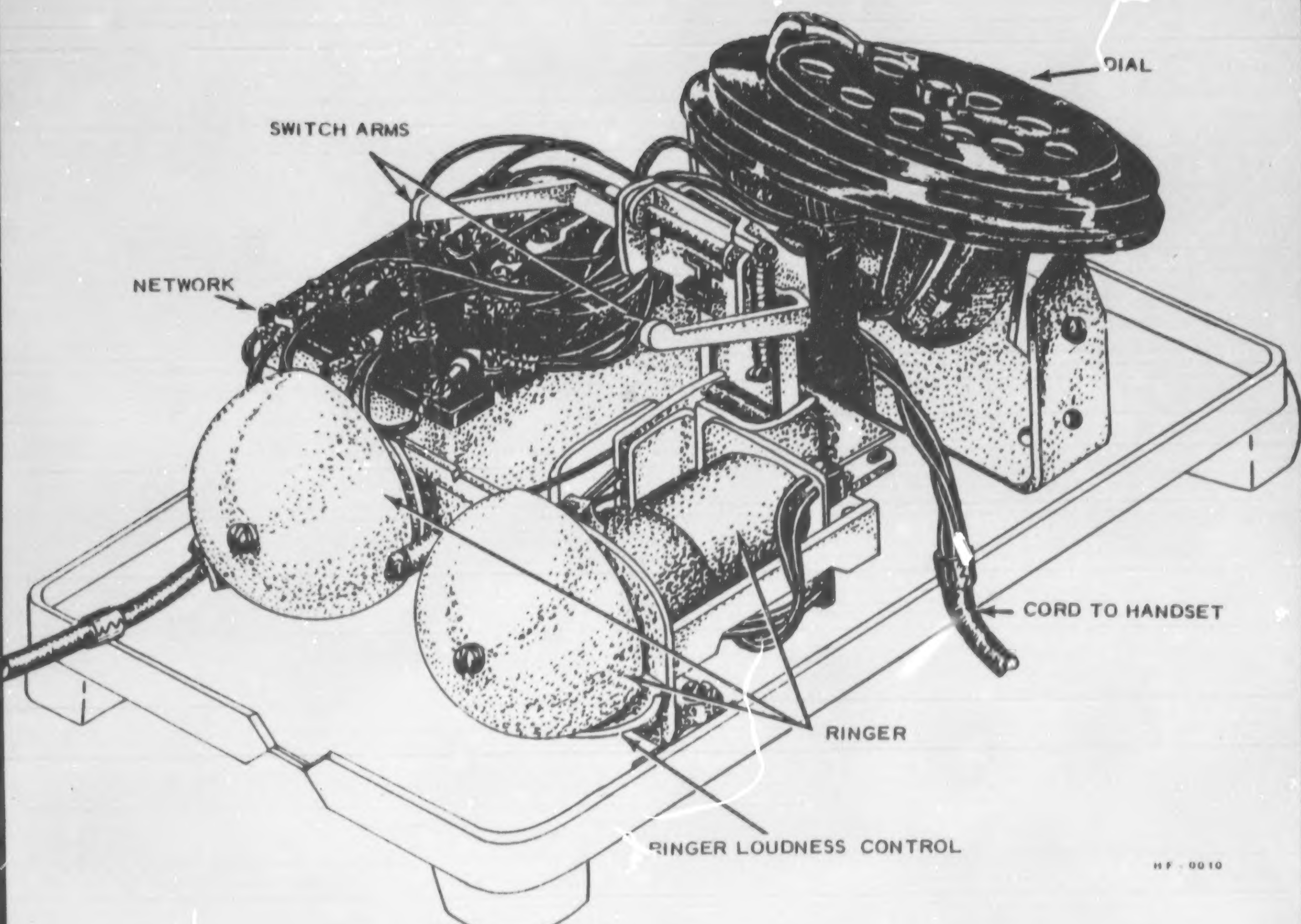
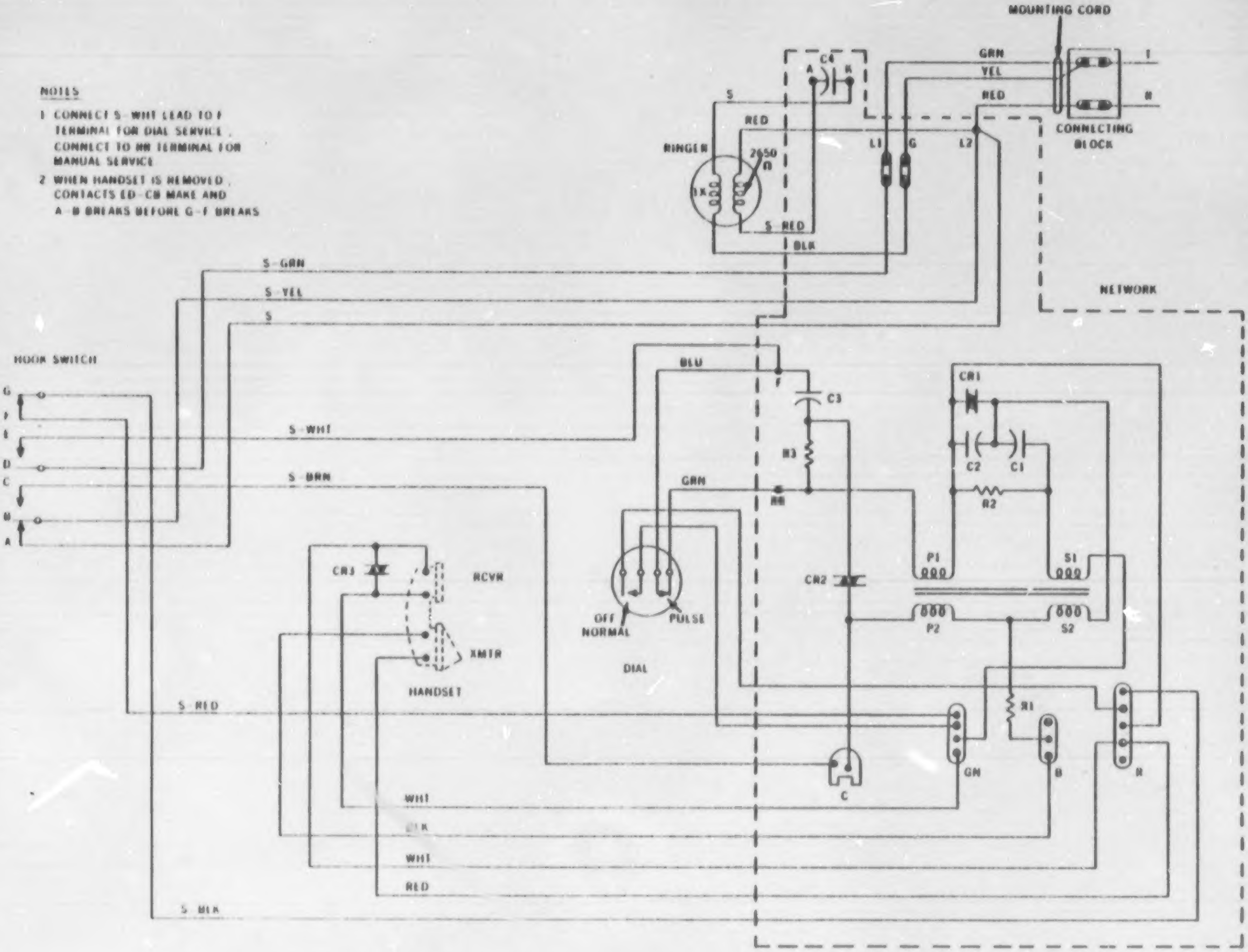

DIAL
SWITCH ARMS
NETWORK
CORD TO HANDSET
RINGER
RINGER LOUDNESS CONTROL
HF-0010

Figure 25. Inside view of 500 telephone.



NOTES

1. CONNECT S-WHT LEAD TO F TERMINAL FOR DIAL SERVICE, CONNECT TO RR TERMINAL FOR MANUAL SERVICE
2. WHEN HANDSET IS REMOVED, CONTACTS ED-CB MAKE AND A-B BREAKS BEFORE G-F BREAKS

MOUNTING CORD
GRN
YEL
RED
T
R
CONNECTING BLOCK
C4
A
K
S
RED
RINGER
2650 Ω
3K
S-RED
BLK
L1
G
L2
NETWORK
S-GRN
S-YEL
S
HOOK SWITCH
G
F
E
D
C
B
A
S-WHT
S-BRN
BLU
F
C3
R3
RR
GRN
CR1
C2
C1
R2
P1
S1
P2
S2
CR2
CR3
RCVR
XMTR
HANDSET
OFF NORMAL
PULSE
DIAL
S-RED
R1
GN
B
R
C
WHT
BLK
WHT
RED
S-BLK

Figure 26. Schematic-wiring diagram for 500 telephone.

9-22. When a ground symbol is used on a telephone schematic it usually means a common connection to positive battery. If an earth ground is intended, it is usually so marked on the diagram. This applies to the ground used during telephone installation, such as the connection to a water pipe, a ground rod, etc.

9-23. Before we discuss the circuits of the telephone, let's briefly mention the identification of the tip and ring sides of the line. To provide an easy means of locating the two sides of the line at connecting blocks and terminals, it became the custom during telephone installation to always connect the ring side of the line on the right-hand terminal and the tip on the left. Also it became a practice to use red and green wires inside of a house to connect the lines to the telephone. These same colors are still used today. The red wire is used for the ring side of the line and the green wire is used for the tip. This brings up a term that is frequently used by telephone installer-repairmen. The term is: "RED-RING-RIGHT." The RED wire is the RING conductor and it is connected on the RIGHT. In addition, the RED wire is connected to battery and it is negative in respect to the tip or ground. Now that we have discussed the wiring leading up to the telephone connecting block, let's consider the telephone circuits individually, starting with the ringer circuit.

9-24. *Ringer circuit.* As you study the circuits in figure 26, assume that the conductors are extended from the central office to the telephone connecting block. With the conductors so connected, the central office can extend either battery or ringing current to the telephone. In figure 26 the telephone mounting cord extends from terminals of the network to the connecting block. The green (GRN) conductor goes from the tip terminal at the connecting block to the L1 terminal on the network; the yellow (YEL) conductor from the tip terminal to the G terminal on the network; and the red (RED) conductor from the ring terminal on the connecting block to the L2 terminal on the network.

9-25. The four ringer leads, as you can see in figure 26, are connected to terminals A, K, G, and L2 on the network. By being so connected, the ringer circuit is always completed to the tip and ring leads. For the central office to apply ringing current to the ringer, however, the handset must be on its cradle to disconnect the tip and ring leads from the transmitting and receiving circuits. If you will take a close look at the hookswitch contacts in figure 26, you can see that contacts B-C and D-E are open. Therefore the handset is on its cradle and the tip and ring leads are disconnected from the receiving and transmitting circuit. With the hookswitch contacts in this position, the only circuit that is completed to the central office is the ringing circuit. To make this circuit easy to trace, it is shown individually in figure 27. As we trace the ringing current through this circuitry, see if you can follow the ringing circuit in both illustrations (figs. 26 and 27).

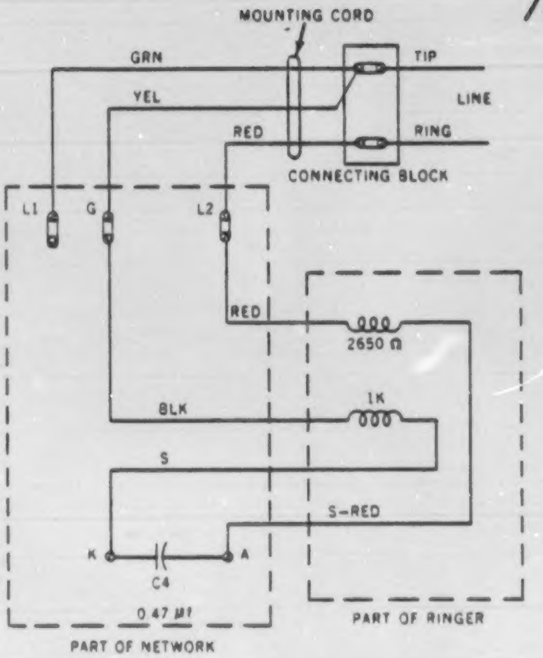


Figure 27. Ringer circuit schematic diagram.

9-26. The ringing current applied by the central office is normally an ac voltage of approximately 85 volts with a frequency of about 20 cycles per second. Since the ringing current is ac, it alternates back and forth in the circuit, first in one direction and then in the other. For the purpose of following the ringing current, however, let's assume that at the instant we are tracing the circuit, the current is leaving the central office on the ring lead and is returning to the central office on the tip lead. Based on this assumption, the ringing current passes from the central office to the connecting block via the ring side of the line and then through the red (RED) conductor of the mounting cord to terminal L2 on the network. From terminal L2, the current passes to the 2650-ohm ringer coil over the red (RED) ringer lead, through the ringer coil and the slate-red (S-RED) ringer lead to terminal A on the network. From terminal A on the network, the current has the effect of passing through capacitor C4 to terminal K. From terminal K, the current passes to the 1000-ohm ringer coil via the slate (S) ringer lead, and then through the ringer coil and black (BLK) ringer lead to terminal G on the network. From terminal G, the current passes over the yellow (YEL) mounting cord lead to the tip terminal on the connecting block, and then it returns to the central office over the tip conductor.

9-27. *Transmitter circuit.* Before the transmitting, receiving, or dialing circuits can operate, the handset must be removed from its cradle. If the handset were removed from its cradle on the set illustrated in figure 26, the hookswitch contacts would change as follows: contacts A-B and F-G would break (open) and contacts B-C and D-E would make (close). In this action the breaking of contacts F-G would remove the short from across the receiver, and the making of contacts B-C and D-E would connect the tip and ring conductors through to the telephone circuitry. In this condition, current would flow from the central office to the telephone transmitter via the tip and ring conductors. Let's trace the path of this current through the telephone transmitter circuit.

9-28. To provide you with an easier path to follow, the telephone transmitter circuit has been redrawn in figure 28. However, you should have no trouble in tracing the path of current in either of the circuits illustrated (figures 26 or 28). When the handset is removed from its cradle, allowing the hookswitch to operate, dc from the central office passes over the ring side of the line to the connecting block and then over the red (RED) mounting cord conductor to terminal L2 of the network. From terminal L2, it passes over the slate-yellow (S-YEL) wire to the operated B-C contacts of the hookswitch and then over the slate-brown (S-BRN) conductor to terminal C on the network. From terminal C, it passes through induction coil winding P2, resistor R1, terminal B, through the black (BLK) conductor of the handset cord to the transmitter, and then via the transmitter and red (RED) conductor of the handset cord to terminal R on the network. After the current leaves terminal R, it passes through induction coil winding P1, terminal RR, the green (GRN) wire lead to the dial, the normally closed pulsing contacts, and then via the blue (BLU) wire from the dial to terminal F on the network. From terminal F on the network, the current passes over the slate-white (S-WHT) wire to the operated D-E contacts of the hookswitch, through the contacts and the slate-green (S-GRN) wire to the L1 terminal, and then over the green (GRN) conductor of the mounting cord to the tip side of the line at the connecting block. From this point, the current returns to the positive side of the battery at the central office via the tip side of the line.

9-29. Note in figure 28 that the transmitter current flows through both primary windings (P1 and P2) of the induction coil. Also note that the current flows through these windings in opposite directions. That is, the current that flows through winding P1 in one direction flows through winding P2 in the opposite direction. Thus with any current change in the circuit, these windings aid each other through the process of induction. Therefore, when someone speaks into the transmitter, causing its resistance to vary, the changing current values in the circuit cause strong voice currents to be induced in the induction coil windings. These voice currents, besides being applied to the network circuits, are applied to the telephone lines leading to the central office. If these lines are connected through to another telephone, the voice currents are applied to the receiving circuitry of that unit. Before we trace these voice currents through the receiver circuits, let's briefly discuss the equalizing feature of the telephone.

9-30. When voice currents are induced in the transmitter circuit, they pass through terminals RR and C of the network assembly. These voice currents are also applied to the tip and ring conductors via the circuitry of the dial, hookswitch, and connecting block assembly (see fig. 28). By the same token, when voice currents are received by the telephone, they enter the circuitry over the tip and ring conductors and go through terminals RR and C via the connecting block, hookswitch, and dial circuitry. To keep the speech volume approximately equal at telephone sets located at varying distances from the central office, the telephone is equipped with an equalizer circuit. The equalizer circuit consists of two parallel circuit paths between terminals RR and C. One of these paths is through resistor R3 and varistor CR2 (see fig. 28). The other path is through winding P1, varistor CR1, and windings S2 and P2. These circuits tend to lower the volume when strong voice currents are applied but offer little opposition to the passage of weaker voice currents.

9-31. *Receiver circuit.* During a telephone conversation the voice currents from the distant telephone are applied to terminals RR and C on the network. These currents, which are varying in nature, pass through windings P1 and P2 in a manner similar to that described for the transmitter circuit. As these varying voice currents pass through windings P1 and P2, they induce an ac voltage in winding S1. This induced voltage in winding S1 causes current to flow to the receiver in the handset. To trace this current in the receiver circuit, refer to figure 26 while reading the following paragraphs.

9-32. The induced voltage in winding S1 causes current to flow from one end of the winding to terminal GN and then through a white (WHT) lead in the handset cord to the receiver

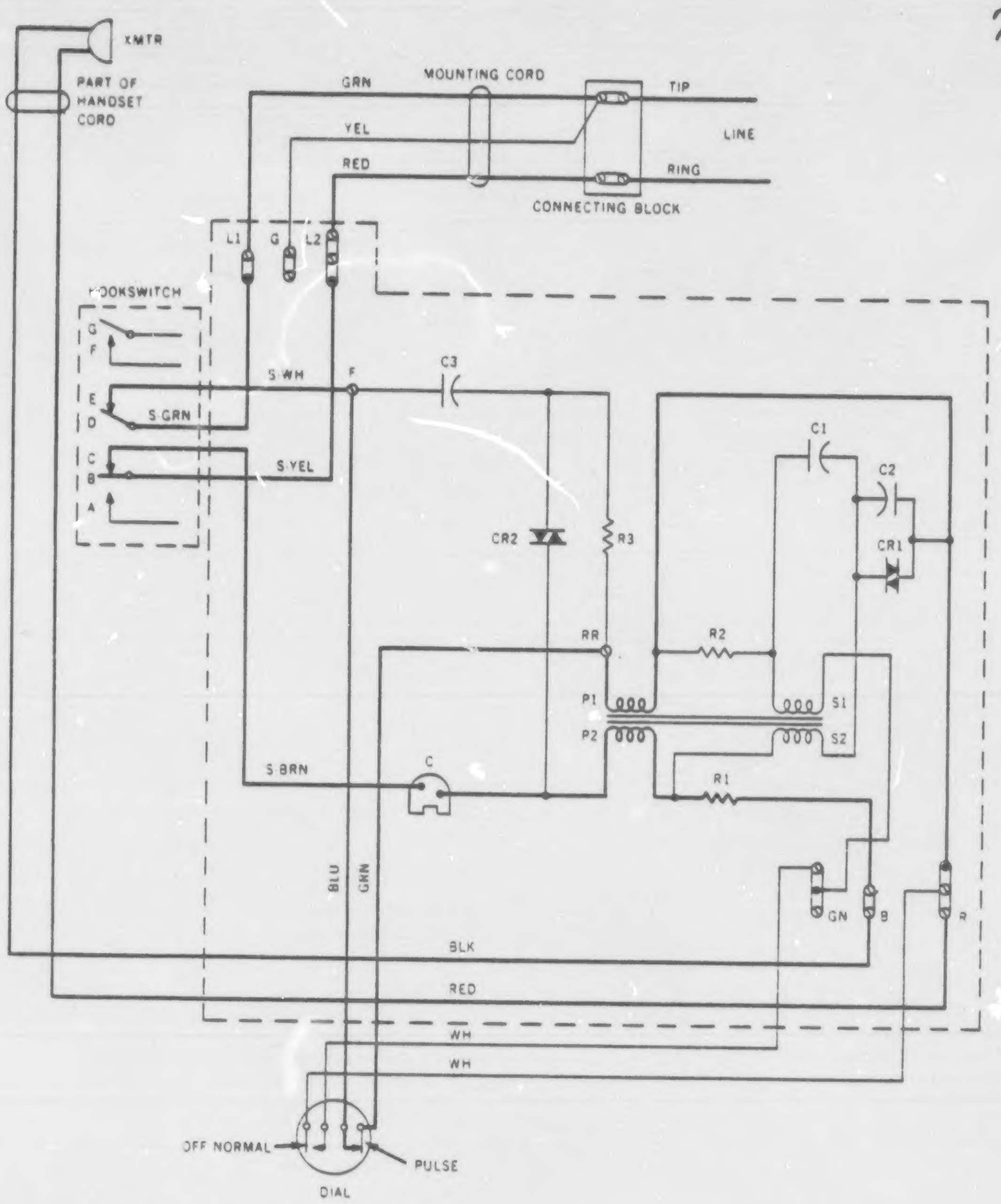

XMTR
PART OF HANDSET CORD
GRN
MOUNTING CORD
TIP
YEL
LINE
RED
RING
CONNECTING BLOCK
L1
G
L2
HOOKSWITCH
G
F
E
D
C
B
A
S-WH
S-GRN
S-YEL
F
C3
C1
C2
CR1
CR2
R3
RR
R2
P1
P2
S1
S2
S-BRN
C
R1
BLU
GRN
GN
B
R
BLK
RED
WH
WH
OFF NORMAL
PULSE
DIAL

Figure 28. Transmitter circuit schematic diagram (500 telephone).

unit in the handset. From here it passes through the receiver unit and then to terminal R on the network via another white (WHT) lead in the handset cord. From terminal R on the network there are four possible paths for the induced current to reach its source at the other end of winding S1. These four possible paths are as follows:

(1) From terminal R through series-connected capacitors C2 and C1 to winding S1.

(2) From terminal R through resistor R2 to winding S1.

(3) From terminal R through varistor CR1 and capacitor C1 to winding S1.

(4) From terminal R through the red (RED) handset cord lead, the transmitter, the black

(BLK) handset cord lead, terminal B, resistor R1, winding S2, and capacitor C1 to winding S1.

9-33. As the current from winding S1 passes through the receiver unit, the receiver diaphragm vibrates, reproducing a sound that is similar to that entering the transmitter at the distant telephone. Thus we hear a sound that is similar to the party's voice as he speaks into the transmitter of the distant subset. While the transmitter and receiver circuits are fresh on your mind, let's consider the antisidetone features of this circuitry.

9-34. *Antisidetone circuit.* As explained previously, the term sidetone refers to the sound that reaches a telephone receiver from the associated transmitter of the same telephone set. In other words, it has to do with how loud you hear your own voice in the receiver as you speak into the transmitter of your telephone. The antisidetone feature then, refers to the circuitry that reduces the sidetone to a desirable level. In the telephone the reduction of sidetone is accomplished by the balancing action of the components in the network. To understand this balancing action, you must remember that the network functions in two different ways during an ordinary telephone conversation. First of all, when voice currents from the telephone line are applied to terminals RR and C, the network functions as a receiving unit by applying strong voice currents to the receiver. Secondly, when you speak into the transmitter, the network functions by applying strong voice currents to the line and at the same time by reducing the strength of the voice currents to the receiver. Therefore, the antisidetone feature is applied whenever you speak into the transmitter. To further explain the antisidetone feature, we will briefly consider the action of this circuitry as it functions during receiving and transmission.

9-35. As we explained, the voice currents that enter this subset from the telephone line are applied to terminals RR and C of the network (see figs. 26 and 28). As these currents pass from terminal C to terminal RR, they pass through winding P2, resistor R1, the transmitter, and winding P1. In addition to this, part of the current that passes through winding P2 flows though winding S2, varistor CR1, and winding P1 to arrive at terminal RR. From this, it is easy to see that the received voice current passes through windings P1, P2, and S2. The voice current that passes through all three of these windings induces an additive voltage in winding S1. Therefore, during receiving, a strong voice current is applied to the receiver unit by winding S1.

9-36. When the handset is removed from its cradle and the telephone is in readiness for use, dc current flows from the central office to the telephone instrument via the telephone lines. This current passes through the same circuitry in the network as was explained in the previous paragraph. That is, it passes through windings P2, S2, and P1 in going from terminal C on the network to terminal RR. Of course, in doing this, it also passes through resistor R1 and the transmitter as well as through winding S2 and varistor CR1. It is important for you to note at this time that the circuit through resistor R1 and the transmitter is in parallel with the circuit through winding S2 and varistor CR1. Because of this parallel arrangement, any change in transmitter resistance (such as caused by sound waves striking the diaphragm) will cause a change in current through winding S2 that is opposite to the changes in current in windings P1 and P2. For example, a decreasing resistance in the transmitter will cause an increase in current through windings S2. With these current changes in opposite directions, the voltages induced in winding S1 by windings P1 and P2 are 180° out of phase with the voltage induced in winding S1 by winding S2. Thus, during transmission, a cancellation takes place in winding S1—reducing the strength of any induced voice currents in the receiver circuit. Also, during transmission part of the changing current in winding S2 passes through resistor R2. This current develops a voltage across R2 that is out of phase with the voltage induced in winding S1. Therefore, sidetone is further reduced in the receiver circuit.

9-37. *Dialing circuit.* When the handset is removed from its cradle on the telephone, a dialing circuit is established to the central office via the telephone lines. The completion of this circuit to the central office is indicated to the subscriber by the presence of dial tone in his receiver. This dialing circuit from the central office through the telephone is actually the same as the transmitting circuits described previously. Dialing current from the central office passes over the ring side of the line to the telephone connecting block. To trace the dialing circuit from the connecting block through the telephone, refer to figure 28. From the ring conductor at the connecting block, the dialing current passes through the red (RED) conductor in the mounting cord to terminal L2 on the network. From terminal L2, it passes over the slate-yellow (S-YEL) lead to contacts B-C on the hookswitch, through the B-C contacts and a slate-brown (S-BRN) lead to terminal C, and then through three parallel paths to terminal RR. These three parallel paths from terminal C to terminal RR are as follows:

(1) From terminal C through series-connected varistor CR2 and resistor R3 to terminal RR.

(2) From terminal C through the series circuit formed by windings P2 and S2, varistor CR1, and winding P1 to terminal RR.

(3) From terminal C through winding P2, resistor R1, the transmitter and handset conductors to terminal R, and then through winding P1 to terminal RR.

9-38. From terminal RR the dialing current flows over the green (GRN) dial lead to the pulsing contacts on the dial; through the pulsing contacts and the blue (BLU) dial lead to terminal F, through terminal F and the slate-white (S-WHT) lead to contacts D-E on the hookswitch; through the D-E contacts and the slate-green (S-GRN) lead to terminal L; through the green (GRN) mounting cord lead to the tip terminal on the connecting block; and then to the central office via the tip conductor of the telephone line. During dialing, of course, the pulse contacts on the dial open and close the circuit the same number of times as the number of each digit dialed. During the dialing of each digit, the off-normal contacts close, shorting out the receiver circuit via the white (WHT) dial leads. The shorting out of the receiver circuit keeps the subscriber from hearing the dial pulses in his own receiver. Without this feature the dial pulses would be heard as loud clicks in the handset receiver. One more feature of dial operation is that capacitor C3 and resistor R3 form a capacitance resistance bridge across the pulsing contacts of the dial. The bridge circuit protects the pulsing contacts from excessive arcing and burning during the dialing operation.

9-39. This completes our discussion of the 500 telephone. Before we move on to the next chapter, however, let's briefly discuss some of the other telephones used by the Air Force.

10. Other Telephones

10-1. The parts and circuits described for the 500 telephone are used in many telephone configurations. Let's mention a few examples of such units. Wall telephones, both 554 and 558 series, use the same parts and circuits as the 500 telephone. The main difference between these sets and the 500 unit is in the shape of the base and housing components which facilitate wall mounting. Another example is in the 564 and 565 key telephones which use the same parts and circuits. Also the 630 and 631 series of call director telephones use basically the same parts and circuits. Since so many of these telephones use the same components and circuitry, it is evident that if you understand the 500 telephone you will have little trouble in understanding the operation of these other telephones. In addition to this, we must point out that you may become involved with telephones that use the components and circuitry explained in Chapter 1 of this volume.

10-2. In addition to these telephones, there are the explosionproof and weatherproof sets, used at some Air Force installations, especially at missile sites. Explosionproof phones are used in areas where they may be exposed to combustible gas. As shown in figure 29, the circuit components, excluding the handset, are inclosed in a cast aluminum housing. This prevents electric arcing in the telephone from igniting fumes or gas in the area outside the telephone set. All connections to the set are sealed and the line wires are placed in a conduit that is attached to the set by threaded connections, which are also sealed to prevent gas from entering the housing.

10-3. At some installations, explosionproof and weatherproof connecting stations are provided. To use this type of station, you just plug in an explosionproof headset and transmitter assembly. When weatherproofing only is required, the subset is normally inclosed in a weatherproof box or cabinet which is sealed against the entrance of moisture. The internal components of explosionproof and weatherproof telephones are the same as the components used in ordinary

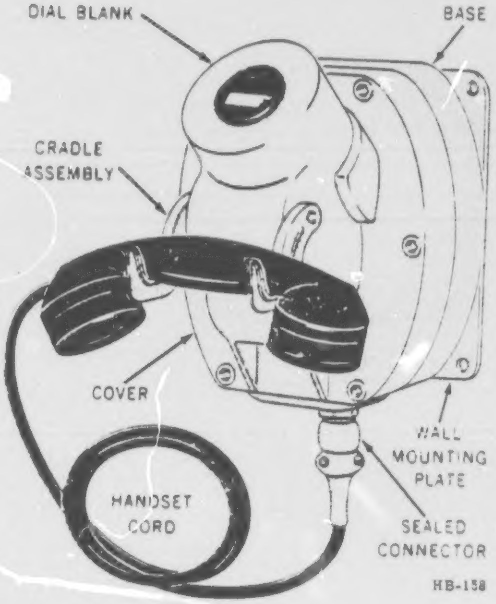


Figure 29. Explosionproof wall type telephone.

telephones, the principle differences being in the explosionproof and weatherproof housings and in the methods used for sealing against the elements.

10-4. This concludes our discussion of the station equipment used with automatic systems. The next chapter pertains to maintenance and inspection systems and records. However, before you study the next chapter, complete the review exercises for this one.

NOTE: CHAPTER 3 HAS BEEN DELETED DUE TO MILITARY SPECIFIC MATERIAL.

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Telephone Station Maintenance, Troubleshooting, and Repair

AS AN installer-repairman you are responsible for the maintenance of telephone sets used on your base or installation. You must be able to maintain these along with their associated circuits and equipment. In other words, you are responsible for the maintenance of the telephone equipment that extends from the terminal of the telephone line or cable through the telephone sets in the installation. This equipment includes the lead-in or drop wiring, extending from the terminal on the telephone pole to the building; the protector assembly (for lightning, etc.) mounted on the building; the inside wiring and connecting blocks; and the telephone sets with their associated apparatus.

2. Generally, maintenance is divided into two categories: preventive and corrective. Preventive maintenance eliminates most service breakdowns and therefore reduces the need for repairs. Corrective maintenance locates and removes troubles that have caused service breakdowns. When the trouble is located, it is generally corrected by repairing, adjusting, or replacing the defective component. In this chapter we shall first briefly discuss preventive and general maintenance procedures, including inspections and treatment to control corrosion; secondly, we will discuss telephone test equipment, including telephone test sets, test receivers, and multimeters; and thirdly, we will cover fault location and repair of telephone sets and components using test equipment.

16. Preventive Maintenance and Corrosion Control

16-1. Preventive maintenance includes inspection and other work done on equipment to keep it in good working condition so that breakdowns and interruptions in service are held to a minimum. This type of maintenance is normally accomplished by making systematic inspections of the overall installation and by then correcting or repairing any defects found. As an installer-repairman, you may have to perform preventive maintenance inspections on the telephone installations at your base. Furthermore, you must do preventive maintenance while working on other jobs. For example, when you are installing or repairing a telephone set, you must inspect the associated equipmemt (pole terminals, drop wiring, connecting blocks, etc.) and make necessary repairs. Generally speaking, inspect the associated equipment as follows:

a. Terminals. Examine the wiring and connections at the pole terminals to make sure that all connections are in good condition and that the drop wiring is properly attached to the pole.

b. Drop wiring. Examine the drop wiring that extends from the pole terminal to the protector block on the building to insure that it is in good condition, properly attached, and that it has adequate clearance from trees, powerlines, cables, buildings, etc.

c. Protectors. Examine the protector assembly on the building to make sure that it is grounded, properly attached, and that its protector mechanisms (carbon blocks, fuses, etc.) offer maximum protection to the circuit components.

d. Station wiring. Inspect the station wiring that extends from the protector on the outside of the building to the telephone connecting blocks inside of the building to insure that it is in good condition and properly attached. Also, examine the connecting blocks along the station wiring to insure that they are not borken or damaged.

16-2. **Corrosion Detection.** When you inspect the terminals, wiring, protectors, etc., pay special attention (especially in damp climates) to detect the possible formation of corrosion. When you find corrosion, take corrective measures to eliminate it; and prevent, if possible, its future occurrence. You must know what corrosion is and what must be done to prevent it, if you do your job properly.

16-3. Corrosion eats away material, usually metal, by rusting, electrochemical reactions, etc. It would be difficult to explain all of the corrosive actions that can take place in telephone equipment. However, in most instances, we find that moisture has contributed at least a part in any damage caused by corrosion.

16-4. Corrosion usually starts when moisture in the air reacts with metals. Also, it occurs when a chemical compound in a solution breaks up into charged atoms or ions as a result of electric current. Oxygen is also essential in any serious corrosion; but normally, corrosion does not take place in the atmosphere without water in some form being present. With most types of corrosion, the initial rate of formation is much faster than that which occurs later, because the initial oxide film sets up a protective coating that slows down the corrosion process.

16-5. Corrosion continually converts metals back to their original state; for example, iron reverts to natural iron oxide—ore. Corrosion attack varies on different metals; but the basic nature of corrosion is almost always the same. Electricity flows between areas of a metal surface through a solution which can conduct an electrical current. This electrochemical action eats away the metal.

16-6. **Corrosion Control.** Corrosion can be controlled in many ways, ranging from washing and cleaning to sand blasting and applying some type of protective coating. It can also be controlled by shelters, covers, and containers. This is especially true when the shelters or covers prevent moisture from entering the apparatus. It is important that these methods be used by all personnel concerned. In the telephone substation area, you can eliminate most corrosion troubles by installing the proper materials in the right way, by installing moisture-proof materials in damp areas or climates, and by placing the wiring and apparatus inside the building where it is not affected by moisture, chemical fumes, heat, etc.

16-7. All telephone equipment and attachments meant for outside use are protected from corrosion by either zinc or galvanized coatings, or they may be made from metals or materials that will not rust or corrode. Aluminum, copper, plastic, bakelite, and procelain are frequently used. The materials used outside are usually made so that weather, rain, snow, hot sun, and winds will neither damage the material nor cause circuit breakdowns during the normal usable life of the item. Normally, if sepecifications are followed during installation, there is little danger of corrosion damage to the part of the telephone equipment that is out in the weather. It is the rest of the equipment, the connecting wiring, and inside parts that usually cause the trouble.

16-8. *Prevention.* To prevent troubles inside of the building or installation, the wiring, terminals, connecting blocks, etc., must be placed so that dampness cannot damage them. Sometimes this may call for a special kind of wire or rerouting the wire to a dryer location. The damage to the insulation might not be called corrosion by a strict interpretation, but if the insulation is destroyed, shorts and grounds may occur and cause an interruption to service. Also, if corrosion forms on terminals, not only can it destroy them, but in severe cases, it may cause a short between the connections.

16-9. Corrosion is easier to prevent than it is to cure. A small amount of planning may save hours of labor in troubleshooting and changing instruments. The prevention of corrosion at a substation installation depends largely upon planning the installation of the telephone equipment in such a way that it will withstand the conditions existing at the particular location. Ordinary telephones should not be installed in places where excessive moisture can cause damage. Where moisture does exist, the possibility of installing weatherproof apparatus should be considered.

16-10. *Correction.* When you find corrosion in a piece of equipment, you will probably have to replace the affected part. This may be the only method available to get the equipment back in operation but, at the time of replacement, possibly you can do something to prevent the recurrence of corrosion. Another type of instrument, moving part of the equipment, a rerouting of the cable or wire—any of this might prevent the same thing from happening again. The piece of equipment that has been damaged by corrosion will need cleaning and adjusting and will quite likely need drying out. To put it back in operating condition, remove all traces of corrosion, rust, and moisture. Also, clean and adjust all of the contact points.

16-11. When planning installations and while performing preventive maintenance inspections, remember that prevention is the easiest part of corrosion control. Detection of corrosion is a matter of performing frequent inspections of any suspected installation. Correction is the biggest job of all, if the situation is allowed to get that far.

16-12. It is quite often necessary to inspect the entire telephone subset during preventive maintenance inspections. The complete inspection of the subset will be covered later in this chapter along with testing and repair. Before we discuss such items as test equipment, testing, and repair, let's consider some general maintenance procedures.

17. General Maintenance Procedures

17-1. The maintenance of telephone sets, once they have been installed, consists mostly of locating troubles and making the necessary repairs. Troubles in telephone sets or circuits are indicated by the fact that some part of the subset or circuit is not functioning properly. Symptoms of trouble indicate failure or malfunction of any one of the four operations of the telephone set: (1) signaling the operator or seizing the automatic switching equipment, (2) receiving the ringing signal, (3) transmitting sound, and (4) receiving sound.

17-2. When you have isolated the trouble to one of these operations, you are well on your way toward troubleshooting. Sometimes studying the information on the form (service order, work order, etc.) that dispatched you to the subset location helps you find the trouble. The information on this form usually includes the location of the telephone set, the wire or cable pair involved, the telephone number, the trouble reported, and in many cases, its probable location. As you analyze the information on this form, you may find that a schematic diagram will help you to localize the trouble in the subset area. In every case, make a visual inspection of the wiring and connections as we explained previously. Remember, this visual inspection is very important since it may disclose the cause of the trouble.

17-3. If you see no broken wires or connections, you then make continuity, voltage, and resistance measurements with the proper instruments, using a systematic process of elimination. You can thus locate troubles in the minimum amount of time. Start this check from a point in the circuit that is known to be good. Successive parts of the circuit can then be checked and eliminated until the fault is located.

17-4. Frequently more than one factor may be causing the trouble in the subset. Consequently you should follow a thorough step-by-step procedure to localize and eliminate each source of trouble. Be sure that you follow these procedures to completion even though the immediate cause of trouble has been discovered in one of the earlier steps, because you might find dirty connections or points of probable breakdown, which could later develop into serious trouble.

17-5. This is the step-by-step procedure you should follow. First, determine the exact nature of the trouble. Often troubles may be exaggerated or underestimated because they are reported by people unfamiliar with the operation of telephone circuits. Second, check the equipment for obvious faults; examine the equipment and wiring for mechanical damage. For example, determine whether the telephone set has been dropped or otherwise damaged.

17-6. Before testing any of the subset circuits, test at the aerial cable terminal, or, in large buildings that are so equipped, test at the telephone terminal cabinet. The proper terminals for the circuit will have been identified by the wire chief; therefore the test at these terminals is to determine that the source of trouble does not lie on the central office side of the equipment. If the trouble is on the central office side, report it to the wire chief, but you must still check the subset to determine its working condition. Test the subset by contacting the central office and requesting the wire chief to furnish the terminal numbers of a spare pair. You can do this by using a test set like the one shown in figure 37. To do this simply connect the test set to the terminals of a good pair and call the central office. In a dial system you must dial the number of the test desk by using the test set dial.

17-7. When the pair is assigned, connect the test handset across the spare terminals to determine whether or not that pair is good. Then connect the telephone set to be tested to the new terminals, call the test desk, and request that the test desk operator run a transmission test on the telephone. If a regular test desk is not available, the wire chief can make the transmission test from a test board. The wire chief should also test the ringer by signaling over the line.

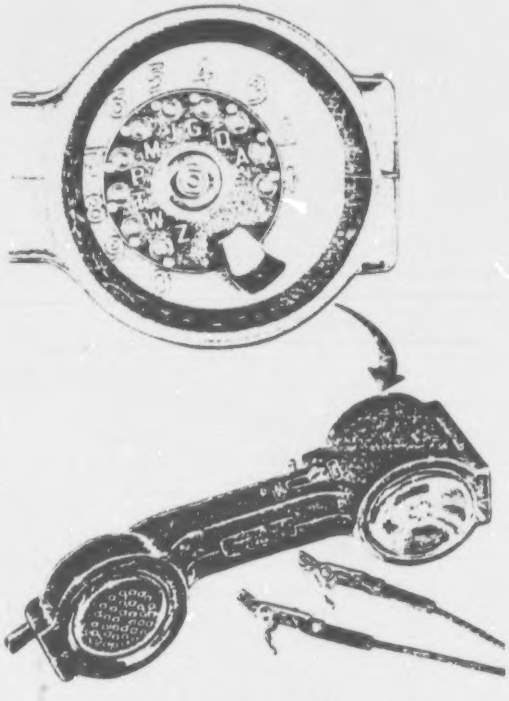


Figure 37. Hand test set (TS—365/GT).

17-8. If any of the above tests indicate that the trouble is in the substation, that trouble should be isolated by following specific procedures. Before you test the subset equipment, test the inside wiring (wiring inside the building extending from the connecting block to where the telephone wire enters the building) by removing the cover from the connection block and disconnecting the leads from the telephone. Connect the test handset across the terminals on the connecting block and call the test desk. If you find defective inside wiring, replace it without attempting to determine the exact location of the trouble.

17-9. Telephone trouble may sometimes result from failure of the telephone user to handle the instrument properly. If such is the case, you should instruct him in proper telephoning techniques. Nevertheless you should test the general operating condition of the equipment.

17-10. We have already referred in general to the wire chief's test desk and to the necessity for conferring with the wire chief during troubleshooting procedures. Another operation in which the wire chief plays an important part in the location of substation troubles is that before you are dispatched to troubleshoot a circuit, he determines the general situation. For instance, he will be able to tell you the type of service (dial or manual), the type of equipment, and the effect of the trouble on the telephone user's service.

17-11. The wire chief performs tests before the installer-repairman is sent out. First, the wire chief must complete tests to make sure that the trouble is definitely outside of the central office. Second, he completes a transmission test to determine the condition of the subset transmitter and receiver. Of course he can run this test only when the telephone is not completely out of order.

17-12. In addition to these general testing procedures, testing instruments can also be used to advantage.

18. Test Equipment

18-1. To locate telephone troubles systematically, the installer-repairman must use various instruments. This is necessary because in many cases the circuits are inclosed or are so arranged that it would be very difficult to examine each one visually. Furthermore, an endless task confronts you when you attempt to inspect each part of a component or circuit every time trouble occurs. Some systematic and logical method of inspection must be followed if the cause of the trouble is to be localized quickly. The best method is first to isolate the trouble by identifying it with one of the circuits or systems. The next step is to trace out that particular circuit or system until the failure is uncovered. To help you with the isolation and location of troubles, the Air Force furnishes several types of test instruments. The test instruments shown in figures 37 and 38 are typical of the instruments the installer-repairman uses. Figure 37 shows a telephone test set and figure 38 shows a multimeter that is representative of those used in telephone maintenance work. Let's consider these instruments in more detail.

18-2. **Telephone Test Set.** Figure 37 illustrates the TS-365GT handset, typical of the telephone test sets used by the installer-repairman. Note that this set is equipped with a dial that allows you to call into a dial exchange. Just clip the leads to the conductors or terminals of an operational line or cable pair and then dial the exchange after you receive a dial tone. When someone at the exchange answers, you can then carry on a conversation with him, or you can arrange for the test desk operator to check the circuit. In addition to this, you can use this set to determine if voltage is present on a circuit. Do so by listening for a click in the receiver when you connect the leads across the line or cable pair. You can identify the ring or battery side of

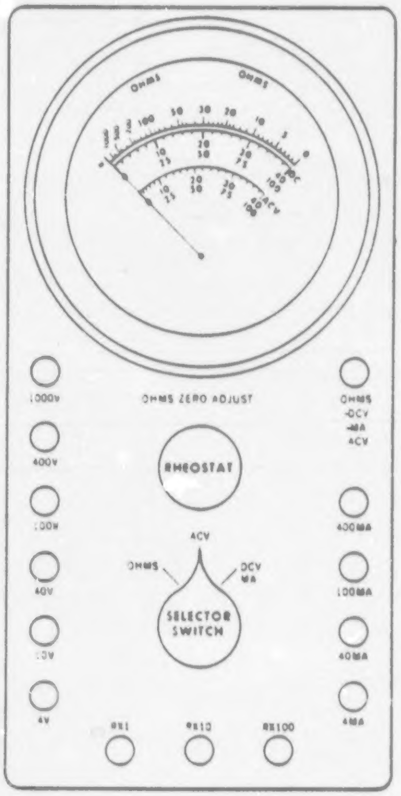


Figure 38. Multimeter (TS—297/U).

the line by connecting one lead from the test set to ground and then by touching the other test set lead first to one side of the line and then the other. When the ring or battery side of the line is touched with the test set lead, a loud click should be heard in the receiver. Also, with an automatic system, dial tone may be heard when the test set lead is touched to the ring or battery side of the line.

18-3. **Receiver Click Set.** The receiver click set may be the only test device available to you for making continuity tests. You should remember that these tests indicate when a circuit is complete. When current flows through the receiver in a completed circuit, it creates a magnetic force which moves the receiver diaphragm. Hence you hear a click.

18-4. Figure 39 is a schematic diagram of a receiver click set. In this illustration, a telephone receiver and battery are connected in series with two test leads. Arranged in this manner, the set is used for testing circuits that have no source of power. When the circuit has its own source of power, the battery is not used in the click set circuit. When the click set has no battery, it can be used only on powered circuits; and generally speaking, it must be used in series with the circuit.

18-5. To construct a click set using telephone components, you may use the standard telephone handset or a receiver headset. You must also have a 4½-volt battery. When you use a telephone handset in this way, remove the transmitter cap and transmitter element, as shown in figure 40. Inside the handset transmitter cavity, depending on the type of handset, either you will find two terminals that are connected to the receiver element through the handle of the handset or you will find that the receiver conductors of the handset cord extend through the handle to terminals on the receiver. In either event the click set can be constructed as shown by A, B, and C in figure 40. Note that the construction of a click set in this way connects the receiver and battery in series, as shown by the schematic diagram in figure 39.

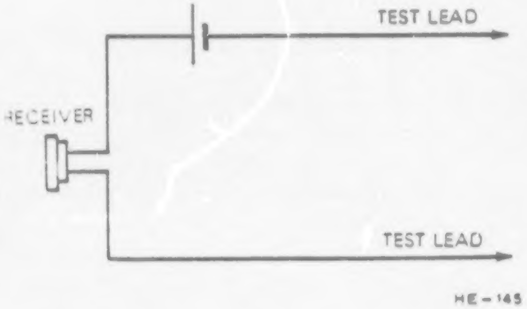


Figure 39. Receiver click set (schematic diagram).

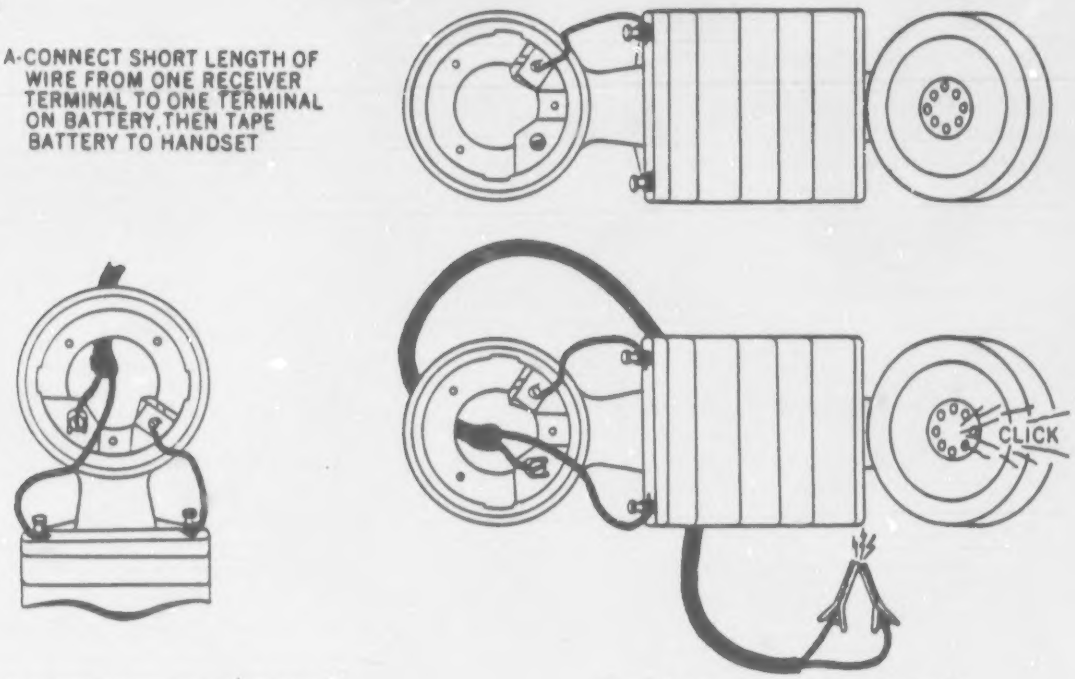
18-6. A click set is simple to use. Suppose you want to check the circuit through a lamp from point 1 to 2, shown in figure 41. Since the click set is complete with its own battery, you need only to complete the circuit. At the time your test leads touch the two points as shown, you should hear a distinct click in the receiver. If you do not hear a click, the circuit between points 1 and 2 is incomplete. To prevent wrong interpretation, be sure you make all circuit tests carefully. Remember, sometimes corrosion at the contact points prevents current flow.

18-7. Now that we have covered the click set and telephone test set, let's next consider the use of multimeters.

18-8. **Multimeters.** The multimeters used by the telephone equipment repairman are measuring tools that provide essential information about electrical circuits. But no matter how good those tools are, the results will be only as good as the knowledge and ability of the person using them. Learn all that you can about the use of multimeters for testing telephones and telephone circuits. As you already know from your studies in Volume 1, the heart of any multimeter is the meter (sensing) mechanism, called the *meter movement*, which can be used to measure varying amounts of voltages, currents, and resistance.

18-9. To measure different amounts of voltage, resistors with different resistance values are switched in series with the meter circuit, as shown in figure 42. As you can see in the illustration, the resistors, called multipliers, are switched in series with test leads A and B and the basic meter movement. When a large resistance value is switched in series with the circuit and the scale on the meter is calibrated for this resistance, the meter is then capable of measuring a large voltage. By the same token, when a smaller resistance value is switched into the circuit and the scale is calibrated for the smaller value, the meter is then capable of measuring only smaller voltages.

18-10. As you should remember from your studies in the resident course, the basic meter movement is also used to measure different amounts of current. To accomplish this, the resistors (called shunts) are switched in parallel with the basic meter movement. Of course the meter scale must also be calibrated to match the different shunts. Also, as you perhaps recall, the basic meter movement can be used as an ohmmeter by placing a battery and variable resistance in series with the circuit. This, however, requires that the meter scale be calibrated in ohms or some other unit of resistance.



A-CONNECT SHORT LENGTH OF WIRE FROM ONE RECEIVER TERMINAL TO ONE TERMINAL ON BATTERY, THEN TAPE BATTERY TO HANDSET

B-CONNECT TEST LEADS-ONE TO UNUSED BATTERY TERMINAL AND ONE TO FREE RECEIVER TERMINAL

C-TEST CLICK SET BY TOUCHING TEST LEAD TIPS TOGETHER. A DISTINCT CLICK SHOULD BE HEARD

Figure 40. Click set construction.

18-11. In the last few paragraphs we have been thinking of the basic meter movement as it is used to measure direct current values. This is only natural because the meter movement being considered is actually a dc unit. The multimeter, however, can also measure ac values. A rectifier unit (consisting of diodes) is switched into the circuit during ac measurements. Thus the ac values (voltages and currents) are rectified and applied to the meter in dc form.

18-12. *Multimeter operation.* The importance of the multimeter for locating troubles in telephone equipment is great. In fact, your success in locating troubles in telephone equipment will depend largely on your ability to use the multimeter. In the communications shop you may have any one of three models of multimeters available: TS–297/U (Fig. 38), a model 260, or an AN/PSM–6. All three instruments are used to check the same electrical properties, but the PSM–6 and the Model 260 can test over a greater range and with more accuracy.

18-13. When you select a multimeter for a particular job, it is important that you know its capabilities and limitations. To give you some background information in that area, we will briefly discuss the TS–297/U and the AN/PSM–6 multimeters. Since the Model 260 can perform all the functons performed by the PSM–6, we shall use the PSM–6 to represent both units. Any reference to the PSM–6 also applies to the Model 260.

18-14. *Multimeter TS–297/U.* The TS–297/U was *not* designed for the accuracy and degree of application that one would expect of the more elaborate and more versatile multimeters. It does, however, serve its purpose as a light, portable, rugged, and relatively inexpensive field multimeter. This meter has a sensitivity of 1,000

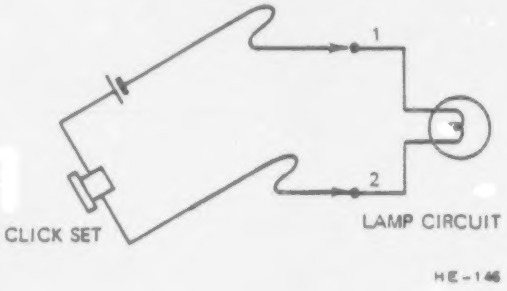


Figure 41. Use of click set.

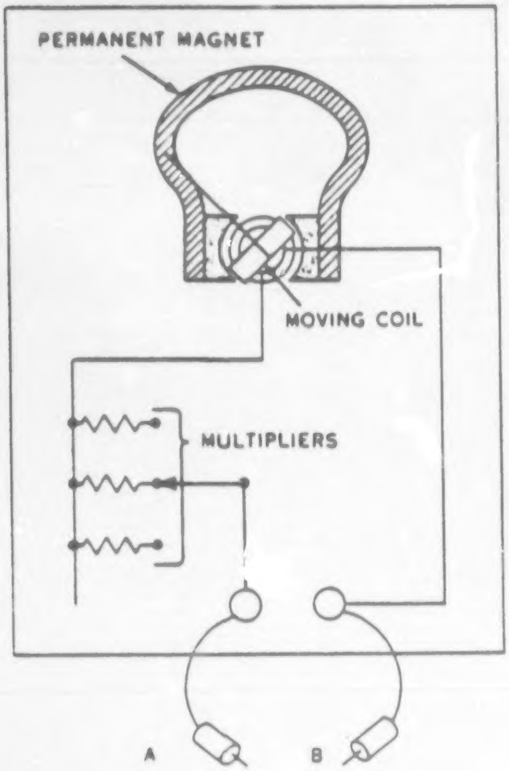


Figure 42 Basic voltmeter.

ohms per volt, and its maximum direct-current measuring capacity is 400 milliamperes (ma).

18-15. Figure 38 is a drawing that represents the face of the TS–297/U multimeter. Observe that this test set has six voltage range jacks, three resistance range jacks, and four direct-current range jacks. The voltage jacks, ranging from 4V (4 volts) to 1000V (1000 volts), appear at the left in the illustration; the resistance jacks, ranging from R × 1 (resistance times one) to R × 100 (resistance times 100), appear at the bottom of the illustration; and the direct-current jacks, ranging from 4MA (4 milliamperes) to 400MA (400 milliamperes), are shown at the right in the illustration. The jack that is common to all measurements is uppermost at the right in the illustration, labeled as follows: OHMS, −DCV, −MA, and ACV. This means that a test lead must be plugged into this jack to perform measurements in ohms, direct-current volts, direct-current milliamperes, or ac volts. The minus mark (−) in front of labels DCV and MA means that the lead plugged into this jack must be used as the negative test lead when measuring dc volts or dc milliamperes.

18-16. While you are still looking at figure 38, note the selector switch located at the lower center in the illustration. This switch must be placed in the correct position. For example, the selector switch must be turned to the OHMS position to measure resistance values; it must be turned to ACV position to measure ac voltages; and it must be placed in the DCV-MA position to measure dc voltages and currents. Finally, in the lower half of the illustration, note the rheostat located in the center just below the meter. The labeling just above this rheostat, OHMS ZERO ADJUST, indicates its purpose. It is used for adjusting the meter pointer to zero on the ohms scale when measuring resistance values.

18-17. Now before we discuss the use of this multimeter, take a look at the scales located on the face of the meter. There are three scales: the OHMS scale, the DC scale, and the ACV scale. Zero on the OHMS scale is located to the right on the face of the meter, but the zero markings for the DC and ACV scales are located to the left on the meter. The OHMS scale is calibrated with one set of numbers ranging from zero to infinity. The DC and ACV scales are each calibrated with two sets of numbers ranging from 0 to 40 and from 0 to 100. To use this multimeter you must be able to interpret the readings on these scales in respect to the position of the selector switch and the test lead jacks being used.

18-18. To perform any test with the TS–297/U multimeter, plug the black test lead into the common jack and the red test lead into one of the other jacks, depending on the test to be performed. For example, if the test is a measurement of volts, plug the red test lead into a voltage jack that corresponds to the amount of voltage to be measured. Also, set the selector switch in the proper position for the test being performed. Finally, the scale to be read on the meter during a test depends on two things: the position of the selector switch and the jack in which the red test lead is inserted.

18-19. With the selector switch in the ACV position, as shown in the illustration, we know that we must read one of the ACV scales during an ac voltage measurement. If the red test lead is plugged into the 4V, 40V, or 400V jack, the reading must be taken on the 0 to 40ACV scale. When the red test lead is plugged into the 10V, 100V, or 1000V jack, the reading is then taken on the 0 to 100ACV scale. To interpret these readings, you must consider the position of the red test lead. For example, when the red test lead is plugged into the 4V jack, 4 volts applied between the test leads will cause the meter to read full scale; therefore, during this test, 40 on the scale is read as 4, 30 on the scale is read as 3, etc. By the same token, when the red test lead is plugged into the 400V jack, 40 on the scale is then read as 400, 30 is read as 300, etc. When the red test lead is plugged into the 10V jack, 100 on the scale is then read as 10, 75 is read as 7.5, 50 is read as 5, etc. Also, if the red lead is plugged into the 1000V jack, 100 on the scale is then read as 1000, 75 is read as 750, etc.

18-20. In the above paragraphs the explanation given is for the measurement of ac volts. To make dc measurements, of either volts or milliamperes, the selector switch must be turned to the DCV–MA position. With the selector switch in this position, all readings are then taken on the DC meter scales. Other than this, the making of dc measurements is exactly the same as for ac. Of course, when making dc measurements you must observe polarity by using the black test lead for negative and the red test lead for positive. Also, when making either ac or dc voltage tests, you must always connect the test leads across (parallel to) the circuit; and when making current (MA) tests, you must always connect the test leads in series with the circuit. Furthermore, when measuring either currents or voltages, you must always select a range large enough to insure less than full-scale deflection of the meter. For example, suppose that you are going to measure the voltage in a circuit that has approximately 500 volts applied. In this case you should plug the red test lead into the 1000V jack to make the measurement; otherwise, the voltage of around 500 volts would overload the meter. This is true when you measure either voltages or currents. You must always select a range that is above the value expected in the circuit.

18-21. Now that we have covered voltage and current measurement with the TS–297/U, let's consider the measurement of resistance. To measure resistance values with this meter, you must switch the selector to the OHMS position and plug the red lead into one of the three resistance positions, shown at the bottom in figure 38. After this has been done, the red and black test lead prods must be shorted together and the rheostat adjusted to bring the pointer to zero on the OHMS scale. After the pointer has been adjusted to zero, the test lead prods are then separated to remove the short. With the meter so adjusted, resistance values are measured by connecting the test prods directly across the circuit or its components. *It is important to remember that the power for this test is provided by a battery in the multimeter; therefore, the circuit or component being tested must be disconnected from its power source.*

18-22. The next thing that we must consider is how to read the OHMS scale. This is rather simple because the reading depends upon which one of the resistance jacks is being used. For example, if the red test lead is plugged into the RX1 jack, the reading obtained on the OHMS scale is read directly. This means that a reading of 20 on the OHMS scale is equal to R times one (R × 1) or 20 ohms. As another example, if the red lead were plugged into the RX10 jack and the pointer on the meter showed 20 on the scale, the reading would then be equal to R times ten (R × 10) or 200 ohms. From these examples, you can see that the amount indicated on the OHMS scale is always multipled by the value shown on the resistance jack in use; therefore, with this multimeter, the amount shown on the OHMS scale is multiplied by either 1, 10, or 100. *Another important factor about the ohmmeter is that whenever the red test lead is changed from one resistance jack to another, the pointer on the meter must be readjusted to zero before any additional resistance tests are performed.* Whenever the meter cannot be adjusted to zero, you will probably have to replace the multimeter battery.

18-23. *Multimeter AN/PSM–6.* This multimeter, usually called the PSM–6, is illustrated in figure 43. Briefly, it is designed to measure dc voltages up to 5,000 volts, alternating-current voltage up to 1,000 volts, direct-current values up to 10 amperes, and resistance values up to 10 megohms. The PSM–6 uses a precision 50-microampere movement which has 1,700 ohms resistance. The movement is connected to the calibrated circuits through multiple switches: the FUNCTION switch and the RANGE switch. All of the connections are brought out to the two test lead jacks at the bottom of the panel. The meter has provision for dual sensitivities of 20,000 and 1,000 ohms per volt. The higher sensitivity does not affect the circuit (load the circuit) under test as much as the lower sensitivity does. Thus the high sensitivity setting makes more accurate measurements. The lower sensitivity increases the versatility of the instrument, because there are many items of electrical equipment whose voltage and resistance charts specify the use of a 1,000-ohms-per-volt meter. Now that we have discussed the general capabilities of the PSM–6, let's see how it works, beginning with the operating controls.

18-24. As you can see in figure 43, a drawing that represents the face of the PSM–5, there are three control knobs located near the bottom of the multimeter panel. Two of these controls, the FUNCTION and RANGE switches, were mentioned before. The other control located just below the meter at the center of the panel, is the ohms ZERO adjustment.

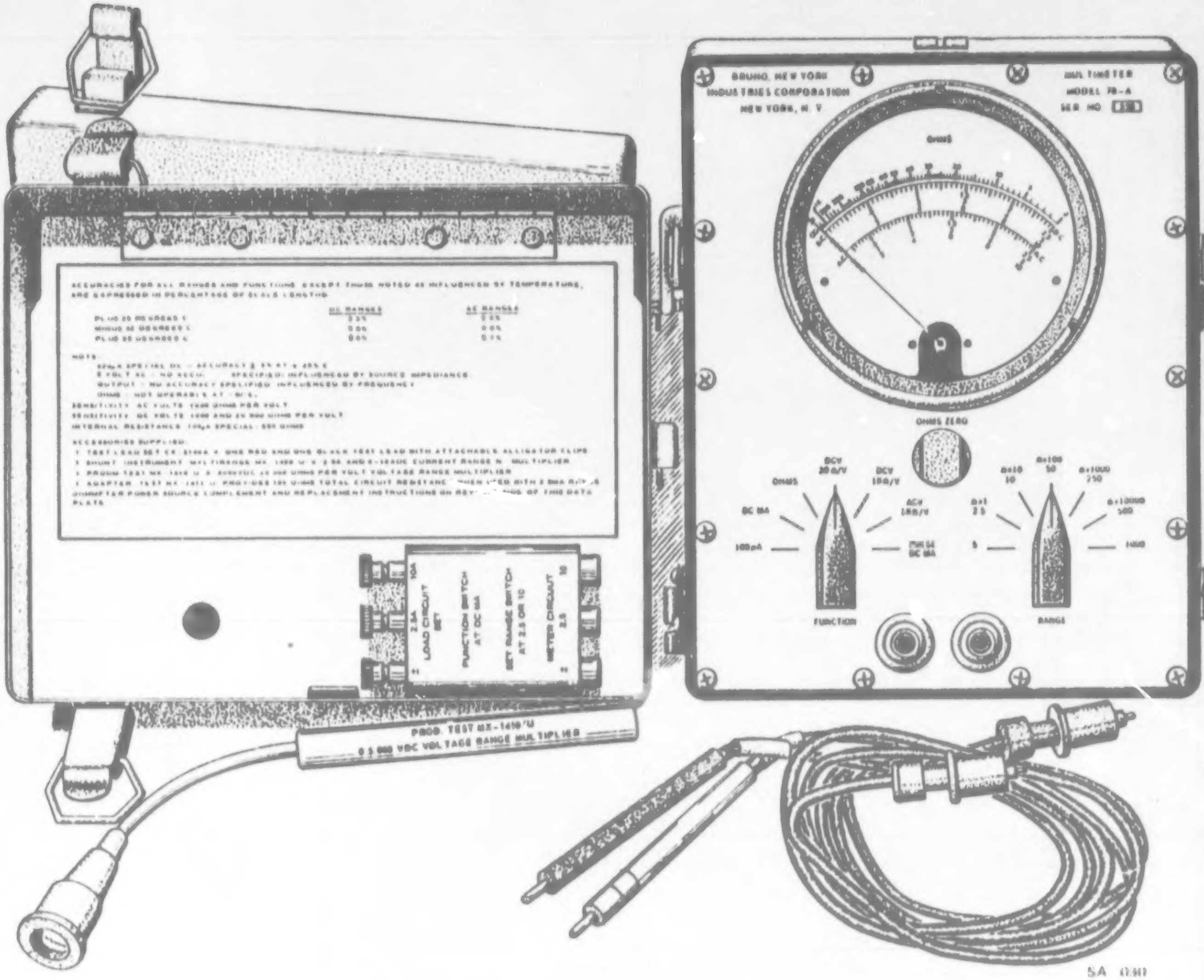

BRUNO, NEW YORK
INDUSTRIES CORPORATION
NEW YORK, N. Y.
MULTIMETER
OHMS
OHMS ZERO
DCV 20 Ω/V
DCV 1 KΩ/V
ACV 1 KΩ/V
OHMS
DC MA
100 μA
FUNCTION
RANGE
LOAD CIRCUIT SET
FUNCTION SWITCH AT DC MA
SET RANGE SWITCH AT 2.5 OR 10
METER CIRCUIT
10A
2.5A
PROD. TEST MX-1410/U
VDC VOLTAGE RANGE MULTIPLIER
SA 030

Figure 43. Multimeter (AN/PSM-6).

18-25. The FUNCTION switch is a seven-position switch that selects the proper circuit elements to measure either voltage current, resistance, or output voltage level.

18-26. The RANGE switch is a seven-position switch used to select the specific range of voltage, current, resistance, or output level for the desired measurement so that an accurate indication can be secured.

18-27. The ZERO control is used on resistance ranges to zero the pointer when changing resistance ranges or to compensate for changes in battery voltage.

18-28. Now that we have identified the purpose of the control switches, let's discuss the various ranges of this multimeter. We will first consider the scales on the meter face, then the ranges controlled by the FUNCTION and RANGE switches, and the meter accessories.

18-29. The scales on the face of the meter are also shown in figure 43. There are three scales: OHMS, AC, and DC. There is one set of numerals on the OHMS scale ranging from 0 to 3K. Of course, numerous readings can be obtained on this scale by using the different multipliers (R × 1, R × 10, etc.) controlled by the RANGE switch position. The AC and DC scales both have three sets of numerals ranging from 0 to 2.5, 0 to 5, and 0 to 10. How these scales are read when making a measurement depends upon the position of the control switches. As you study the various ranges of the meter, you should keep in mind that depending on the position of the RANGE switch, the AC or DC scales may be read in the following ways. The 0 to 2.5 scale may be read as 0 to 2.5 or as 0 to 250. The 0 to 5 scale may be read as 0 to 5, 0 to 50, or 0 to 500. The 0 to 10 scale may be read as 0 to 10 or 0 to 1,000 on either scale; and as 0 to 100 on the DC scale for the special 100-microampere measurement. You should also remember that when the 0 to 5 scale is used as a 0 to .5 scale, you must imagine the point to be in front of each number on the scale. As an example, the numbers 1, 2, 3, 4, and 5, are read as .1, .2, .3, .4, and .5.

18-30. With the FUNCTION switch set in the DCV–20KΩ/V position, the multimeter circuitry provides 20,000 ohms per volt during the measurement. When this range is used, the meter has very little effect on the circuit being tested. High sensitivity makes it possible to secure accurate readings even when testing high resistance circuits carrying small amounts of current. With the FUNCTION switch in the above position, the RANGE switch is used to select the desired measurement range. The following ranges for the measurement of dc voltages may be selected by the RANGE Switch: 0 to .5 volts, 0 to 2.5 volts, 0 to 10 volts, 0 to 50 volts, 0 to 250 volts, 0 to 500 volts, and 0 to 1,000 volts.

18-31. With the FUNCTION switch in the position described in the previous paragraph, and by adding Accessory Probe MX–1410/U, you can use the PSM–6 to measure voltages up to 5,000 volts dc. Briefly, this is done as follows: With the master set up to measure 500 volts dc, plug the accessory probe in series with the positive test lead from the meter. Attach the clip of the accessory probe to the high voltage test point to be measured. Attach the clip of the accessory probe to the high voltage test point to be measured. After you attach the negative test lead to the negative side of the voltage source under test, apply power to the equipment and you can read the high voltage on the meter. NOTE: When making high voltage tests, be sure that the power is off and that no residual high-voltage, capacitive charge remains at the voltage test point on the equipment under test when connecting or disconnecting the test leads.

18-32. With the FUNCTION switch set in the DCV–1KΩ/V position, the multimeter circuitry provides 1,000 ohms per volt during measurement. When the FUCNTION switch is in this position, 1,000 ohms per volt is provided throughout all of the ranges selected by the RANGE switch. Also, with the FUNCTION switch in this position, the RANGE switch may be used to select any of the voltage ranges, except for the 5,000-volt range. The 5,000-volt range, which requires the use of the accessory probe, is used only with the FUNCTION switch in the DCV–20KΩ/V position.

18-33. When the FUNCTION switch is moved to the ACV–1KΩ/V position, a rectifier is connected to the meter circuit to rectify the ac voltage applied to the meter. The RANGE switch may be used in any of its positions so that the meter can measure ac voltage up to 1,000 volts. The readings on the AC scale are made in the same way as on the DC scale.

18-34. When the FUNCTION switch is set at the OUTPUT position, the circuit is identical to that of the ACV position—except that a series capacitor is added to the circuit. The function of this capacitor is to block any dc component of the ac voltage being measured.

18-35. When the FUNCTION switch is placed in the DC MA position, it actuates the circuitry that is used for all direct-current measurements. With each change in the position of the RANGE switch, the values of the resistors are changed so that all current in excess of 50 microamperes will flow through the meter shunt. To measure current in excess of 1 ampere, the MX–1409/U Multirange Instrument Shunt is used. Adding this instrument shunt increases the current measuring capacity of the PSM–6 to 10 amperes. When you use the MX–1409/U, set the FUNCTION switch at the DC MA position, the RANGE switch at the 10 position, and insert the meter test leads in the 10 jacks on the MX–1409/U. The load under test is then connected to the binding posts of the MX–1409/U. NOTE: Make all "connects" and "disconnects" with the power off.

18-36. When the FUNCTION switch is placed in the OHMS position, it prepares the basic ohmmeter circuit for measuring resistance. Here again the values of the resistors are changed with each setting of the RANGE switch. As explained for the previous multimeter, the OHMS ZERO control on the PSM–6 must be adjusted (with the test leads shorted) to bring the pointer on the meter to zero. This must be done at the start of each resistance test and whenever the RANGE switch is changed to a different position during resistance tests. Also, when the meter cannot be adjusted to zero, it is quite likely that the batteries in the multimeter need replacement.

18-37. With the meter adjusted to zero, any unknown resistance connected in series with the test leads will naturally cause a reading on the meter that is less than full scale. The value of the unknown resistance is then read on the OHMS scale of the meter. For greater accuracy, resistance measurements should be taken with the RANGE switch in the position that allows the pointer to fall upon the part of the scale where the scale graduations are farthest apart. (The two batteries used in the PSM–6 are plastic-coated 12.06- and 1.34-volt mercuric oxide batteries.)

18-38. This position of the FUNCTION switch enables the PSM–6 to measure extremely small amounts of current. The RANGE switch is not included in this circuit. When switched to this position, the circuit is simply a 1,700-ohm resistor shunting the 1,700-ohm meter resistance, thus forming a parallel resistive network of two equal branches. When placed in series with a 100-microampere (or less) current path, the current divides equally between the two branches, deflecting the meter pointer to full scale if the applied current is the full 100 microamperes. To interpret the meter reading with the FUNCTION switch in this position, you must use the 0 to 10 DC scale. Of course, when doing this, you must add a zero to each of the indicated scale values. For example, since a full-scale reading is equal to 100 microamperes, the 10 on the scale must be read as 100, the 8 must be read as 80, the 6 must be read as 60, the 4 must be read as 40, and so on over the entire scale.

18-39. *Using the multimeter*. Since there are so many precautions that must be observed when a multimeter is used, we have purposely condensed most of the information in this section into a series of brief statements. We will first consider general precautions, and then those that must be observed during specific tests.

18-40. During tests, general precautions must be observed. Since all meters are current-actuated devices regardless of their scale calibration, here are hints concerning meters in general:

a. Before using any multimeter, carefully read all the instructions furnished with it.

b. When you use any instrument, the area around the jacks and terminals must be clean and dry. This prevents surface leakage, which can cause error in readings on the more sensitive ranges.

c. The rotary switches on the front panel generally are *not* continuously rotatable. Do not try to force them beyond the first or last position.

d. Do not drop a meter or subject it to excessive mechanical shock.

e. Never try to measure the internal resistance of a meter movement with an ohmmeter, as the movement may be damaged by the high current required for ohmmeter operation.

18-41. Observe precautions when using voltmeters. Although the voltmeter is a high-resistance device and is not so apt to be damaged by an excessive current flow, there are several hints concerning its proper use that you should observe. They are as follows:

a. Always connect a voltmeter in parallel across the portion of the circuit in which the voltage is being measured.

b. Use a range large enough to insure less than full-scale deflection.

c. Observe the proper polarity in connecting the voltmeter across a dc circuit. You can avoid improper meter connections by observing the polarity markings on the meter and by remembering that the black meter leads are negative leads and the red leads are positive leads.

d. Remember that the accuracy of a reading indicated by a voltmeter depends upon the sensitivity of the meter. A voltmeter is a current measuring instrument designed to indicate voltage by measurement of current flow through a resistance of known value.

18-42. Observe precautions when using ammeters. There are a number of precautions that apply particularly to the use of the ammeter. They are as follows:

a. Always connect an ammeter in series with the element through which current flow is to be measured.

b. Never connect an ammeter across a source of voltage, such as a battery or generator. Remember that the resistance of an ammeter, particularly on the higher ranges, is extremely low and that any voltage, even a volt or so, may cause a very high current to flow through the meter, causing damage to it.

c. Use a range large enough to keep the deflection less than full scale before measuring a current. Form some idea of its magnitude, then switch to a large enough range or start with the highest range and work down until you reach the appropriate one. Most accurate readings are obtained at approximately half-scale deflection. Many milliammeters have been ruined by trying to measure amperes. Therefore be sure to read the lettering either on the dial or on the switch positions and select the proper range before connecting the instrument to the circuit.

d. Observe proper polarity in connecting the meter to the circuit. Many pointers have been ruined by a reverse swing due to reversed polarity.

18-43. Observe precautions when using ohmmeters. The two precautions that must be observed when you use the ohmmeter are:

a. Avoid connecting the ohmmeter across circuits in which voltage exists. Therefore, to remove all power from the equipment, remove the power plug, and discharge any capacitors connected in the circuit under test.

b. Make all resistance measurements with your hands holding the insulated portion of the test prods. The resistance of the human body, under certain conditions, is low (less than 50,000 ohms) and may cause erroneous readings.

18-44. This completes our discussion of the test sets that may be used in telephone maintenance and repair. We will next discuss fault location and repair of telephone sets, including the use of other telephone test equipment.

19. Fault Location and Repair of Telephone Sets

19-1. Thus far we have discussed mostly the procedures used in locating and eliminating troubles between the pole terminal and the telephone mounting cord. The information given in the telephone trouble report is often a clue to the location of the fault. For instance, the subscriber reports the trouble symptom as "The bell doesn't ring." If no other trouble symptom is listed, and you can talk and receive over the set, there is good reason to believe that the trouble is within the instrument (telephone set). The probable causes for troubles in telephone sets are listed in troubleshooting charts for the telephones concerned. As an installer-repairman you should have access to telephone troubleshooting charts at your station of assignment.

19-2. By careful analysis of the trouble reported and by line testing you may isolate the trouble to the telephone set. Replacing the telephone set with another is usually the quickest means of restoring service. However, if service can be restored more quickly by repairing the faulty telephone set, do so. This brings us to the problem of testing the telephone set.

19-3. **Preliminary Testing Procedures.** There are three basic procedures to follow when you are troubleshooting a telephone set. (1) Make on operational check to determine which circuit in the set is not operating properly. (2) Make a visual inspection of the set to discover any obvious faults, such as opens caused by broken wires or connections, shorts caused by improper contacts between spade clips, and improper mechanical action caused by the presence of foreign materials. (3) Make a continuity test to determine if the circuit under test is complete when the trouble is not obvious enough to be seen during the visual check.

19-4. *Operational tests.* After any troubles between the pole terminal and the telephone have been eliminated, operational tests should be performed to isolate the trouble in the telephone set. These tests are basically the same as the initial tests performed at the time of telephone installation. Briefly, to perform these tests you must first inspect the external parts of the telephone, such as the handset, handset cord, mounting cord, telephone housing, and dial assembly. During this inspection, you should verify that the dial does not bind and that the hookswitch mechanism operates freely. When the inspection is completed, there are two tests that must be performed: the transmission test and the signaling test.

19-5. To perform the tramsmission test, first lift the receiver and listen for dial tone. Next, you should blow gently into the transmitter and listen for sidetone in the receiver. While blowing in the transmitter, move the dial slightly off normal. Sidetone in the receiver should be cut off by this action. After checking for sidetone, dial the number of the wire chief, operator, or a local telephone set. While dialing you should hear no dial clicks in the receiver and the ringer bells should not tap. Finally you should carry on a conversation with whoever answers the telephone, noting how well both voices are heard during a normal conversation. Also you should blow gently into the transmitter during the conversation and note whether any scratching or sizzling noises are heard. While the conversation is still in progress, shake, twist, and stretch the handset and mounting cords to see if any scratching or sizzling noises are heard. Noises indicate that these cords are in poor condition. If the above tests are unsatisfactory, the telephone should be either repaired or replaced, depending on the nature of the trouble. If all of the tests are satisfactory, you should then proceed with the signaling tests.

19-6. To perform the signaling test you should dial the ring-back number (if the central office is so equipped); otherwise, call the wire chief or operator and have him ring the telephone under test while you observe the operation of the ringer or bells. The bells should ring clearly and at the proper volume. Also, while the signaling test is being made, move the volume control (loudness control lever) from the highest position to the lowest position and note whether the volume change is appropriate.

19-7. *Localizing trouble.* If the telephone set does not operate properly during the above tests, it may be best in some cases to install another set and take the old one to the shop for additional inspections and tests. But, if you have plenty of time and it is not too urgent that service be established immediately, it may be easier to localize the trouble while the set is still installed. At least by using the telephone test set, you should be able to localize the trouble to one of the five basic circuits of the telephone set. These basic circuits, as shown in the troubleshooting sections of Technical Order 31W1–1–281, *Telephone Sets and Associated Apparatus,* are: the ringing, talking, receiving, dialing, and the short-on-line circuits. You should isolate the trouble to one of these circuits in order to use the troubleshooting charts. To do this with a telephone test set, you must open the telephone and connect the clips of the hand test set, with the switch in MON (Monitor) position, across the telephone line at the subset terminals. This places the test set in a position that allows you to monitor the operation of the subset during a test situation.

19-8. With the hand test set connected across the line terminals as explained above, the trouble symptoms and circuit at fault can be determined as follows:

a. Remove the handset from its cradle on the telephone subset and then listen to the receivers of both the telephone and the hand test set. If nothing is heard in either receiver, the symptom is said to be a "No dial tone (NDT) situation." On troubleshooting charts, this indicates trouble in the short-on-line circuit—which could be either a short or an open in the line circuit through the telephone.

b. With the handset still off its cradle while you are listening to both receivers, hearing dial tone in the receiver of the test set and nothing in the receiver of the telephone indicates a "Cannot hear (CH) situation." This further indicates that the trouble is in the receiving circuit.

c. Next, with the handset off its cradle, operate the subset dial while listening to both receivers. If you hear dial tone in the receiver of the test set and also hear it between digits in the receiver of the subset, you have a "Cannot break dial tone (CBD) condition." This further indicates that the trouble is in the dialing circuit. Also, if you hear nothing in the receiver of the telephone set after the dialing is started and you hear hesitant or distorted dial pulses in the receiver of the test set, it indicates a "Cannot dial (CD) condition." This also indicates trouble in the dialing circuit.

d. Next, with the handset on its cradle and a ringing condition on the line, if you hear the ringing generator in the receiver of the test set and there is no ringing of the telephone, it indicates a "Bell does not ring (BDR) condition." This indicates trouble in the ringing circuit.

e. Finally, if you hear nothing in either receiver when someone is talking into the transmitter with the handset off its cradle, it indicates a "Cannot be heard (CBH) situation." This localizes the trouble as being in the talking circuit.

19-9. If the trouble is isolated to one of the five circuits during the tests, you can perhaps pinpoint the trouble within that circuit by studying the schematic diagram for the telephone and circuit. Many of these diagrams are contained in the technical order referred to previously. In any event you will have to use the diagrams to trace and test the telephone circuits and components if the subset is taken to the shop for repair. For the purpose of this text, let's assume that the subset must be replaced and that we are going to repair the old one in the shop. This brings us to the job of inspecting the subset and of testing its components and circuits. With this assumption let's first consider the inspection of a telephone and then the testing of its components and circuits.

19-10. **Telephone Inspection.** When a telephone has been brought into the shop for repair, it should be thoroughly inspected before any repair work is begun. Of course, in some cases the inspection may be performed at the subscriber's residence, but in the majority of cases when a trouble has been isolated to the telephone, it is best to replace the unit and bring the old one in for inspection and repair. The complete inspection of a telephone is accomplished by examining all of its major components very thoroughly. To do this, let's start with the telephone handset.

19-11. *Handset inspection.* To inspect the entire handset, you must remove the receiver and transmitter units. First remove the transmitter and receiver caps by turning them in a counterclockwise direction. When hand pressure is insufficient to unscrew the caps, a tool is provided for use with the F-type handset. This tool is normally not used on the later model (G-type) handsets. When this tool is not available, or the handset is a model on which the tool cannot be used, the application of a few layers of friction tape around the cap will give a better grip for hand removal. After the caps are unscrewed, remove the transmitter and receiver units and perform the following inspections.

a. Inspect the caps and handset case for chips, cracks, damaged threads, and distorted contacts. If any of these parts are damaged, replace them as needed.

b. Inspect the transmitter unit to see if it is bent or distorted or if the diaphragm is punctured, dirty, or wet. If the unit is defective in any way, replace it.

c. Inspect the receiver unit for dents, dust, and moisture. Clean and test the unit when required. If defective, replace the unit.

d. Examine the handset cord and wiring for frayed insulation near its connections, and check connections for good condition and tightness.

19-12. *Ringer inspection.* To inspect the ringer or any of the internal parts of the subset, you must remove the telephone housing. After the housing has been removed, inspect the ringer as follows:

a. Examine the ringer assembly for secure mounting, make sure that the gongs are not loose, and see that the loudness control lever can be moved freely.

b. Inspect the ringer coils for nicks, dents, and loose connections. Test the ringer coils as described in the section on testing.

c. Examine the biasing spring; if it is broken or lacks tension, the ringer assembly must be replaced.

19-13. *Hookswitch inspection.* In general the hookswitch may be inspected in the following manner.

a. Inspect springs for bent or rusty condition and for pitted contacts. Make sure that the contacts make and break properly.

b. Test for free lever action. If the mechanism squeaks or binds, it is defective.

c. When the spring pileup is defective, it may be replaced on some telephone sets but on others the entire set must be replaced. Check with your source of supply and read pertinent technical orders to determine which parts are available for replacement.

19-14. *Induction coil inspection.* When the telephone set has an induction coil that is not part of a network, it may be inspected in the following manner.

a. Inspect the induction coil for secure mounting and make sure that all of the wiring connections are tight and in good condition.

b. Inspect the windings for nicks, dents, and breaks. Replace the coil assembly if it is damaged.

c. If the coil appears to be in good condition, test the resistance of the windings as explained in the tests section.

19-15. *Network inspection.* If the subset is equipped with a network assembly, the network may be inspected as follows:

a. Inspect the assembly for dents, chips, and broken terminals. Examine all wire connections and tighten loose terminals.

b. If there is any doubt about the network, test its windings as explained in the test section.

19-16. *Housing inspection.* Inspect the housing for cracked, chipped, or discolored condition. Check the padded feet on the base to insure that they will not damage or mar desk finish.

19-17. *Dial inspection.* The telephone dial should be inspected in the following manner.

a. Examine the dial for secure mounting and tighten any loose screws.

b. Inspect the finger stop and finger wheel for loose or bent condition and examine the number card for cleanliness, tears, and legibility. Replace any damaged parts by following the instructions in the pertinent technical order.

c. Insure that all wire connections are tight, and test the dial for proper operation, including the testing for proper dial speed. This must be done by following the instructions for the dial test equipment used in your organization.

19-18. *Cord inspection.* Inspect the handset and mounting cords for cut or frayed insulation and for poor connections or loose cord stays. Furthermore, the cords should be tested for continuity, as we will explain later in circuit testing.

19-19. *Capacitor inspection.* When the telephone uses capacitors that are not contained in a network, they should be inspected in the following manner.

a. Inspect the capacitor case for any dents, cracks, or leaking fluid. If it is damaged in any way, the capacitor must be replaced.

b. Examine and tighten wire connections as necessary.

c. Test the capacitor if a capacitor test set is available.

19-20. **Testing Telephone Components.** Before testing a component, you must inspect it to make sure that it has no broken leads or dirty, corroded terminals that will interfere with the tests. Also, you must study the schematic diagram of the circuit to see if any of the connected leads will affect the test. If the apparatus connected to a component interferes with the tests, disconnect the wiring. The tests explained in the following paragraphs are accomplished by the multimeter with its FUNCTION switch in position for measuring resistance. Of course you must remember that the scale to be used (RX1, RX10, etc.) depends upon the amount of resistance to be measured. In any event the reading will normally be more accurate when a scale is used that causes the meter to read in the lower half of the scale during the measurement. Now consider the testing of some telephone components.

19-21. *Induction coil.* To test the induction coil, you must measure the resistance of each winding. When you test the windings of the 101A induction coil, if the values vary more than 10 percent from the amounts specified, the coil is defective. The values specified for the windings of the 101A induction coil are as follows: the resistance value of the primary winding is 22 ohms; the value given for the secondary winding is 19 ohms; and that for the tertiary winding is 75 ohms.

19-22. *Network.* The 4258 network is used with the 500-type telephone as well as with many other telephones. To test the resistance in the components of this network, you must make three measurements as follows: (1) the resistance measured between network terminals R and RR should read 135 ohms; (2) the resistance measured between terminals R and GN should be 83 ohms; and (3) the resistance between terminals B and C should be 39 ohms. Remember that because this network also contains capacitors, it may still be defective even when the resistance values are satisfactory.

19-23. *Ringers.* Test the ringer windings by measuring the resistance of each coil. If any value varies more than 10 percent from that specified, the coil is defective. Since there are many types of ringers and bells used, you must look up the values specified for the ringer being tested. It is always a good practice to look up the resistance values for any unit being tested. Don't try to remember specifications.

19-24. *Receiver.* The resistance of a receiving unit should not vary more than 10 percent from that listed for the specific unit. Again, always look up the specifications for the unit being measured. The values for the U1 and HA1 receivers are as follows: the U1 receiver (used in the G-type handset) should have a resistance of about 12.5 ohms and the HA1 receiver (used in the F-type handset) should have a resistance of about 24.5 ohms.

19-25. *Transmitter.* Since the resistance of a transmitter is variable, testing it with an ohmmeter is not very reliable. If you have reason to believe that the transmitter is defective, replace it on a temporary basis with one that is known to be good and continue with the troubleshooting procedures.

19-26. *Dial.* The dial, of course, does not have specified resistance values, but you can check the operation of its contacts by using either the telephone test set or the multimeter. By connecting across the dial contacts, you can check them for continuity when they are closed and for breaking the circuit when they are open.

19-27. *Capacitors.* When a regular condenser tester is not available, a ringing or talking capacitor can be checked with an ohmmeter in the following manner.

a. Disconnect the capacitor leads from their terminals.

b. With the ohmmeter set on its high-resistance scale, connect its leads across the terminals to charge the capacitor.

c. Reverse the leads and touch the capacitor terminals; the ohmmeter should show a momentary deflection (kick) as the capacitor discharges and then recharges in the opposite direction.

d. Reverse the leads (back to the first position) and again touch them to the capacitor terminals. The ohmmeter should again show a momentary deflection as the capacitor discharges.

e. If the capacitor will not load up and discharge in both directions (as indicated by deflections on the meter), replace the capacitor with one that is known to be in good condition.

19-28. This completes our discussion on the testing of telephone components. We will next consider the principles involved in testing telephone circuits. We will use some representative circuits to show the use of a telephone test receiver or click set. Before we discuss these tests, however, we wish to point out that the same type of continuity tests may be performed on any telephone circuit simply by using the wiring diagram (for the sepecific telephone) to trace out the circuit and establish the test points. Also, similar continuity tests can be performed by using either the telephone test set or the multimeter.

19-29. **Testing the Transmitter Circuit.** To cover the general principles of telephone circuit testing, we will explain a continuity check of an example-telephone transmitter circuit in the following paragraphs. With this telephone, if it can neither transmit nor receive, you must check the transmitter circuit before you check the receiver circuit. While studying the transmitter circuit, refer to the simplified diagram shown in figure 44. Note that the RED lead has been disconnected from the R terminal of the induction coil and that

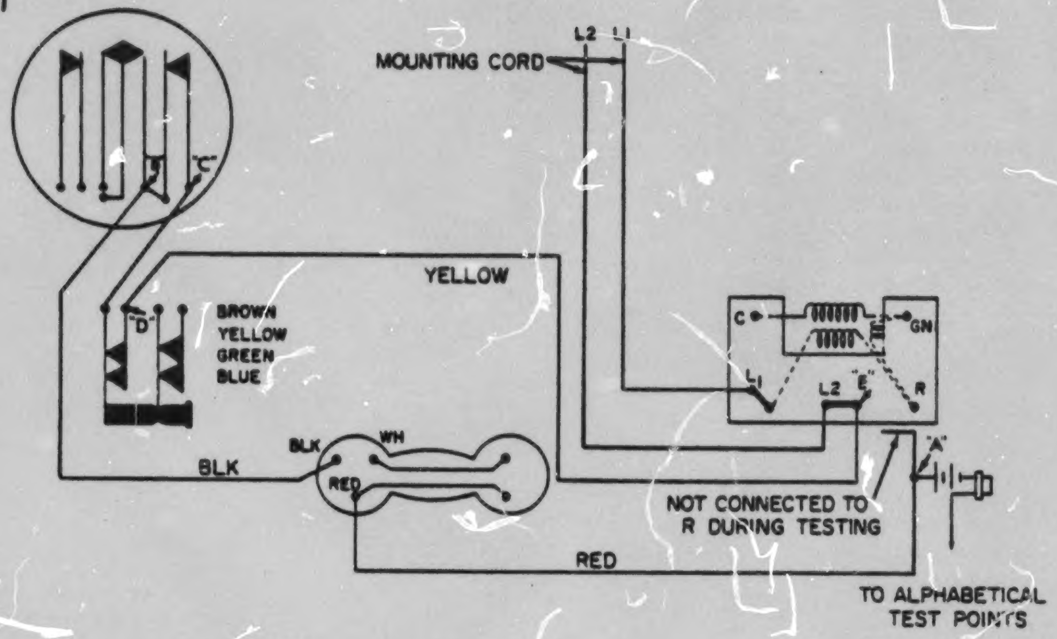


Figure 44. Transmitter test.

a test receiver and battery are connected to the RED lead. This point of connection is identified with the letter A in the illustration, and it is one of the test points used in all of the transmitter tests. The other test lead is extended to points B, C, D, and E as the tests are made. Before we consider the transmitter tests any further, let us examine the circuit components between points A and B in figure 44. You can see that a RED lead extends from test point A to the RED terminal on the handset. Also note that a black (BLK) lead extends from test point B to the BLK terminal on the handset.

19-30. Although it is not shown as such in figure 44, we assume that the telephone transmitter is connected between terminals BLK and RED in the handset. The transmitter, as you may recall, makes contact with these terminals through spring contacts in the handset. With the transmitter in place in the handset, the circuit should be complete from test point A to point B. To test this circuit, connect the test receiver from point A to B and then blow or talk in the handset transmitter as you listen to the test receiver. If the sound comes through the test receiver satisfactorily, the circuit from point A to point B is all right. However, if the sound does not come through the test receiver, the transmitter or one of the connecting leads (RED and BLK) is defective. When this is the case, test the transmitter and each lead separately to determine which is at fault.

19-31. When the test shows that the circuit from test point A to test point B is functioning properly, the transmitter and its leads are not at fault. To perform the next test, then, move one test lead frrom test point B to test point C. This connects the test receiver from point A to point C and allows us to test for continuity through the dial pulsing contacts between points B and C by blowing or talking in the transmitter. If this test is satisfactory, move the test lead to point D to test the continuity of the hookswitch contacts between points C and D. If the hookswitch contacts are satisfactory, move the test lead to point E to test the yellow lead which extends from the hookswitch to the induction coil. If these tests prove to be satisfactory, you can assume that the transmitter circuit is functioning properly. The next test then is that of the receiving circuit.

19-32. **Testing the Receiver Circuit.** The receiver circuit tests are illustrated in figure 45. When you check this circuit, you determine the test results by clicks heard in the telephone receiver only. You should pay no attention to the clicks heard in the test receiver. Furthermore, these receiver tests are performed only after you know the phone transmits. Again the A position is the test set's lead at the disconnected wire of the R terminal, but the B, C, D, and E positions are not the same as those used for testing the transmitter circuit.

19-33. Before we discuss the receiver tests, examine the circuit between points A and B in figure 45. You can see that a RED lead extends from point A to the terminal RED on the handset. Also, note that conductors extending through the handset connect the WH and RED terminals to two receiver terminals at the opposite end of the handset. Although it is not shown in the illustration, the receiver unit (when in place in the handset) completes the circuit between these two terminals. Thus, when the receiving unit is in place in the handset, the circuit should be completed from point A to point B via the RED and WHITE leads and the handset receiver. If this circuit is in good condition, connecting the test leads from point A to point B causes a click in the handset receiver. If a click is not heard when this test is made, it indicates that the circuit between points A and B is at fault. When this is the case, you must test the leads and the receiver individually to locate the faulty unit.

19-34. When the test indicates that the circuit is in good condition between points A and B, move the test connection from point B to point C. This extends the test through the dial and hookswitch contacts, shown between points B and C in figure 45. If you hear a click in the handset receiver during this test, the circuit is in good condition from point A to point C. However, if this test does not produce a click in the receiver, the circuit between points B and C is at fault. (This is assuming, of course, that the previous test showed the circuit from point A to point B to be in satisfactory condition.) To continue the test, move the lead to point D, thus testing the green lead and induction coil winding between points C and D. If this is satisfactory, move the lead to point E to test the leads and capacitor between points D and E. Once again, when a test indicates that the circuit is faulty between two test points, then the components between these two test points must be tested individually to locate the faulty unit.

19-35. **Dial Troubles and Adjustments.** Before we discuss the troubles and adjustment of dials, let's review the actions of the dial and their effects on the telephone circuit. You can see in the circuits of figures 45 and 44 that the receiver and transmitter circuits are wired in series to the hookswitch and the dial pulsing springs (spring contacts between points B and C in figure 44). These pulsing springs are normally closed. They open only while the dial is returning to normal after a number has been dialed. They open and close during this period the same number of times as the digit dialed. For example, if the number dialed is 6, these pulsing springs open and close 6 times in order that 6 electrical impulses may be transmitted to the central office. To keep these pulses from being heard in the receiver as clicks, the receiver is made inoperative during the dialing period by the dial shunting springs, which either open the receiver circuit or short it out, depending on the type of dial used. Furthermore, some dials have additional shunting springs to increase the strength of the electrical impulses. Their action decreases the resistance of the telephone by

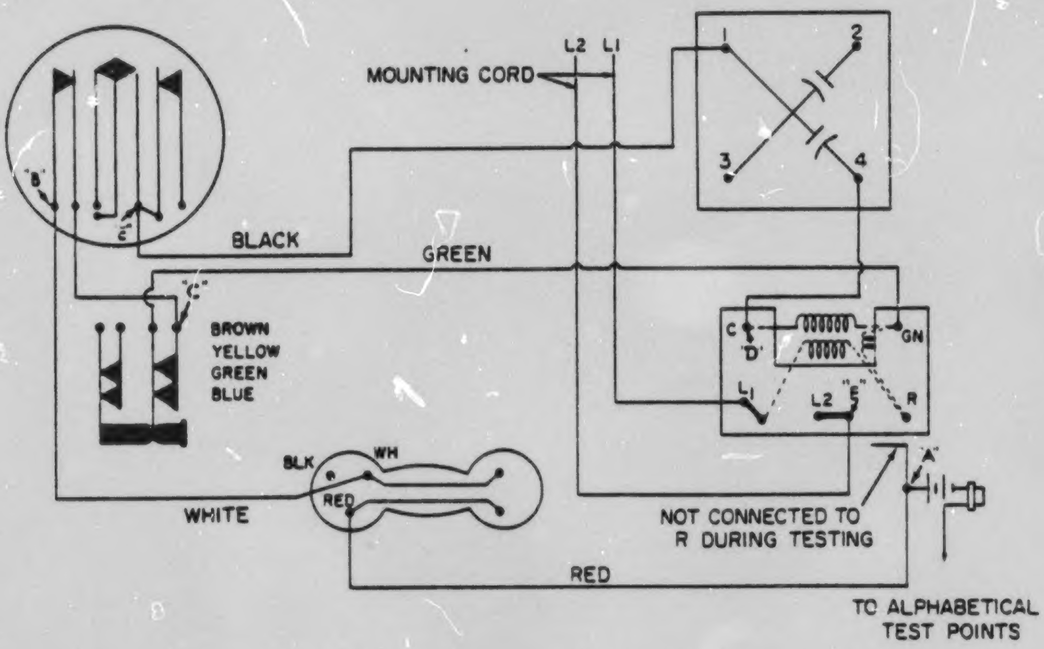


Figure 45. Receiver test.

shorting out either the transmitter or the transmitter and a portion of the induction coil while the dial is not in the normal rest position.

19-36. Dial speed is an important factor in the operation of the telephone system. If dial speed is improperly adjusted, the subscriber will get wrong numbers from correct dialing procedure. With most systems the proper speed is 10 pulses per second, though it can vary slightly and still be effective. The speed is most accurately checked with a dial speed tester. There are various types of dial speed testers on the market. Each tester should be used in accordance with the instructions furnished by its manufacturer. If no test set is available, the speed may be tested (as mentioned before) by stating in an ordinary conversational way the words "one thousand and one" while letting the dial return to its normal position from 0 position of the finger plate. Since it takes approximately 1 second to say this phrase, the dial should stop just as the word "one" at the end of the phrase is spoken.

19-37. The location of dial troubles is comparatively simple but varies with different types of dials. Generally, when looking for dial faults, you check the cleanliness and condition of the spring contacts, see that the moving parts operate properly, and check all wires attached to the dial to make sure that they are tight and not shorting out.

19-38. The dial should require no lubrication for several years. However, under extremely dry circumstances or dusty conditions the bearing surfaces may need lubrication in order to continue their smooth mechanical performance. If it becomes necessary to lubricate the dial, use an approved dial lubricant only. Also, wipe the excess oil from all dial surfaces, as the oil tends to collect dirt. Furthermore, keep oil away from the internal parts of the governor drum. One final statement about the dial—it is probably the best policy to replace the dial assembly whenever it malfunctions. Of course, if a replacement unit is not available, it will then be necessary to correct the trouble to the best of your ability.

19-39. **Hookswitch Maintenance.** The hookswitch used with the modern subset is illustrated in Chapter 2 along with the 500-type telephone. This switch is semipermanently mounted on the telephone base with rivets. The contacts are protected with a plastic cover that is easily removed, when necessary. Normally no adjustment or attention other than cleaning is ever needed on this switch. With other types of hookswitches, however, you may have to adjust the contacts or even replace the switch assembly.

19-40. To maintain or check out the hookswitch on any telephone, you must first understand the operation of its contacts. In many cases you must figure out the various contact positions by looking at the wiring diagram for the telephone concerned. All telephones, however, have certain similarities in the operation of their hookswitches. One operation common to all telephones is that when the handset is placed on its cradle, the hookswitch contacts must disconnect the telephone circuitry (except for the ringer) from the telephone line. Also, when the handset is removed from its cradle, these contacts must connect the telephone circuitry to the line. In addition to the line contacts on the hookswitch, there are other contacts that function in various ways. For example, there are contacts on some hookswitches that disconnect the ringer from the line when the handset is removed from its cradle and reconnect it when the handset is replaced on its cradle. Also, the receiver circuit is disabled on some telephones when the handset is placed on the cradle, and it is reestablished when the handset is removed from the cradle.

19-41. When tests indicate that the hookswitch is not functioning properly it is usually best to replace the assembly, if it is replaceable. When the hookswitch is not replaceable, the subset must be replaced when the malfunction cannot be corrected. In some cases, however, especially when the operating parts are binding, it may be possible to free the mechanism by a small amount of lubrication. If you try this, however, be sure to keep the lubricant off the hookswitch contacts.

19-42. **Ringer Maintenance.** The ringer in the common-battery telephone (either dial or manual) is connected through a capacitor which blocks the direct current and passes the ringing current. It is necessary to block the DC; otherwise there would be a permanent signal on the switchboard at the common-battery central office. Normally this capacitor gives very little trouble.

19-43. On the ringer assembly, one of the two gongs is movable and the other is fixed. The vibration frequency of the two gongs differs to provide a combined effect more pleasing to the ear, and to allow for changing the output for people whose hearing is impaired in the higher frequency range. Up to the point of ringer burnout, the ringer will not suffer demagnetization from line surges due to lightning or accidental contact with powerlines. The ringer coil, coil core, and gongs are the only parts of the ringer that may be replaced at any maintenance level. Do not remove the ringer coil, however, unless facilities are available to remagnetize the permanent magnet. When the ringer magnet loses its magnetism, the bell will not ring until the magnet is recharged. Replace the entire ringer as a unit whenever you find it defective.

19-44. **Network Assembly.** As we explained previously, most of the modern telephones are equipped with a network assembly. Included within this assembly are the transformer (induction coil), capacitors, resistors, and varistors. A terminal board, which forms a cover for the network assembly, contains the terminal screws for connecting the internal wiring and mounting cord.

19-45. The network components are not accessible for inspection or maintenance. The capacitors used in this assembly are self-healing in cases of failure caused by high voltage surges. When a network element is defective, you must replace the entire assembly.

19-46. **Transmitter and Receiver Maintenance.** We have discussed the testing of transmitting and receiving circuits. When such tests show that either one of these units is defective, it is best to replace the defective item with a new or reclaimed unit.

19-47. **Instrument Cords.** The tips of the cords and the conductors near the tips usually suffer the greatest damage from normal wear and from rough and careless handling. For this reason, they require regular and close inspections. When the cord or its tips are defective, replace the cord assembly.

19-48. **Touch-Tone Equipment.** Those keyset components which compare to the regular telephone are inspected, tested and repaired in the same manner as we described in the previous pages. To illustrate, you inspect the handset for chips and damaged threads, the transmitter and receiver for dirt and damage, the hookswitch for free lever action and pitted contacts, etc. In this subset you must also inspect the dial pushbuttons for free movement. Do not attempt to repair the electronic units at the station; install another telephone set and take the suspected set to the shop for maintenance.

19-49. Success in your career field will require effective maintenance of the telephone station equipment. To insure that you understand the information about this equipment which we have presented, you should promptly complete the chapter review exercises in the workbook.

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TELEPHONE EQUIPMENT INSTALLER-REPAIRMAN

(AFSC 36254)

Volume 3

Substation Installation

Extension Course Institute
Air University

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Preface

AS AN INSTALLER-REPAIRMAN, you are responsible for installing and maintaining the telephone station apparatus used by the Air Force. By completing Volumes 1 and 2 of this course, you have learned about telephone principles and telephone instruments (subsets). Very little has been said, however, about connecting the telephone to a cable or line, or about the installation of station wiring and apparatus.

This text (Volume 3) introduces you to telephone installation and presents information on the materials and attachments used in connecting telephones and station apparatus. Also, to cover the principles of installation, some procedural steps are given. It is pointed out, however, that these steps are used only as a means of presenting principles. To install telephone equipment, you must follow the approved procedural steps which are used by your organization.

Some of the materials illustrated in this volume are perhaps not used in making new installations. However, in the performance of maintenance and repair on existing installations, it is quite likely that you will become involved with such items. For this reason and because you are a repairman as well as an installer, it is believed that you should be familiar with materials which are still in use at many Air Force bases.

In addition to the information on telephone installation, this volume explains the methods used in locating troubles in telephone installations and telephone circuits. In doing this, it explains the troubleshooting and testing methods which are used by the installer-repairman.

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Station Planning and Installation Work Practices

ONE OF THE chief responsibilities of an installer-repairman is the installation of telephone subsets. To become proficient in this area, you must first acquire the basic knowledge needed for installation work, and you must practice telephone installation to develop the necessary skills.

2. For the purpose of description and discussion, we can divide telephone installation work into several steps: outside installation, installation of protector, inside wire run, installation of instrument, and connection at the terminal. Although all steps will be considered in this volume, Chapter 1 presents only the basic knowledge which is pertinent to station planning and installation work practices. To present this material, the chapter has been divided into the following sections: (1) definition and description of a typical telephone station; (2) installation planning; (3) tools and work practices; (4) soldering and splicing; and (5) pole climbing equipment and principles.

1. Definition and Description of a Typical Telephone Station

1-1. The installer-repairman must have a thorough knowledge of telephone or substation installation. To fully understand the problems of substation installation, you must first know which components of the telephone system are considered substation.

1-2. **Telephone System.** As you can see in figure 1, the substation includes that portion of the telephone system which extends from the telephone line down to and including the user's telephone set. As shown in this illustration, the telephone system consists of a central office area, a line area, and a substation area. One end of the line area terminates at the central office and the other end terminates at a terminal-can or box which is located near the building and housing area on the base.

1-3. For overhead lines and cables, the terminal-can is normally located on a pole adjacent to the buildings. When underground cable is used, the terminal-can may be located on a pedestal only a few feet above ground or on a pole in the area. In any case, the installer-repairman is responsible for installation and maintenance of the telephone station all the way from the terminal-can down to and including the user's telephone.

1-4. **Substation Area.** Since we have discussed telephone system areas in general, let us now consider the substation area in more detail. By referring to figure 2, you can see the outside portion of a substation. The drop wire which extends from the can on the terminal pole to the bracket on the corner of the building is called the drop. The wiring which extends from the bracket on the corner of the building to the protector is called the drop wire run on the building. The entire length of wire from the terminal pole to the protector is the drop wire run.

1-5. The protector with its ground wire, also shown in figure 2, is a lightning arrester which protects the installation from the high voltages and currents associated with lightning, crosses with power lines, and other conditions. Some of these protectors are equipped with fuses which burn out from excess current. Others may be equipped with carbon blocks which shunt the high voltages to ground. The ground wire serves as a ground for the protector and also as a ground for the telephone circuits on some systems. The wiring

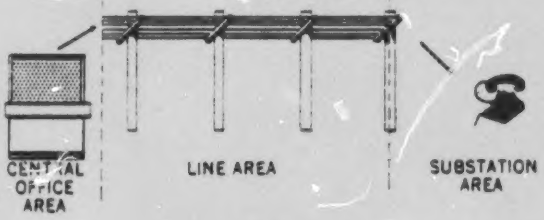


Figure 1. Substation area.

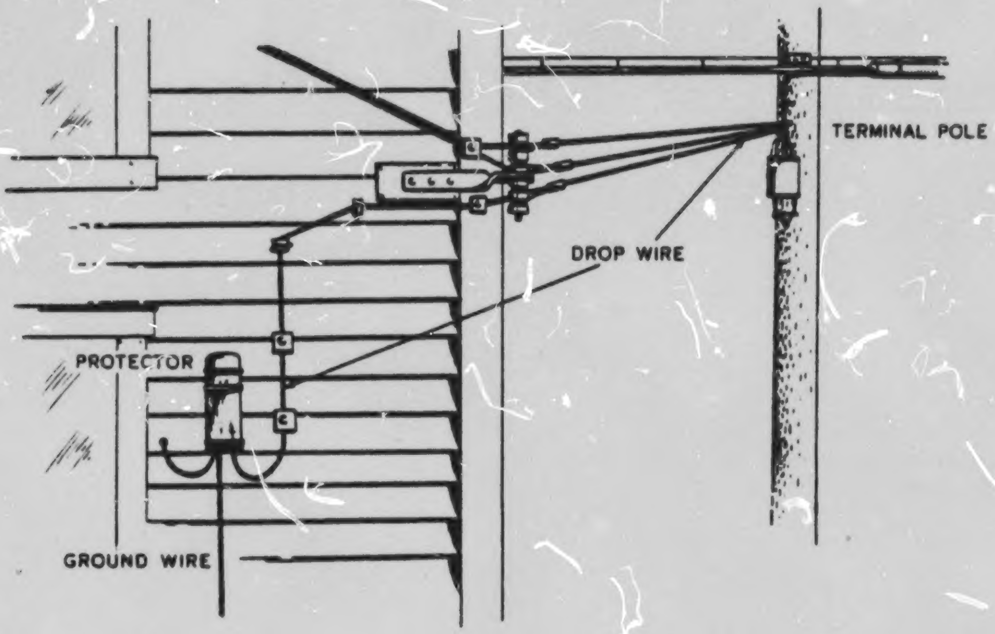


Figure 2. Outside portion of substation.

which leads into the building from the protector is normally referred to as inside wiring. This inside wiring may extend for a considerable distance inside of the building or it may only extend through the wall, as shown in figure 3. In any event, it is normally terminated at a connecting block which permits connection to the telephone cord. In figure 3 the connecting block is shown just inside the wall from the protector, and the telephone cord is shown connected to the block.

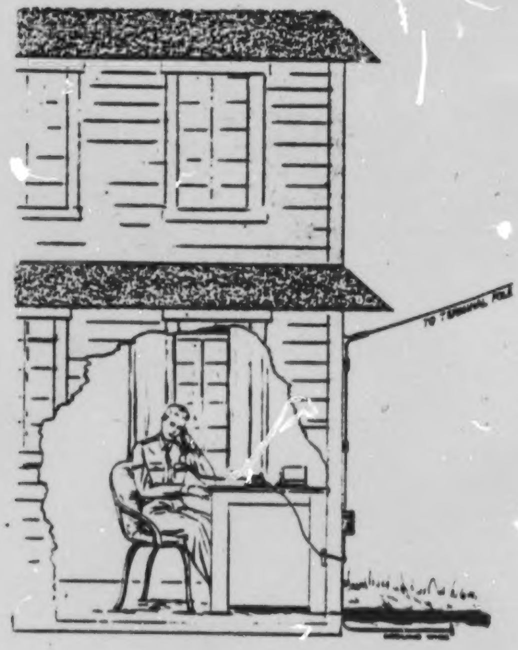


Figure 3. Inside portion of substation.

2. Installation Planning

2-1. As an installer-repairman, you should plan the installation of substations very carefully. A great deal of confusion, many headaches, and much expense may be avoided by following a planned procedure in doing your work. Planning may be defined as the act of prearranging details. Good planning results when such factors as job quality, time, and expense are considered. Determining in advance the steps required for solving a particular problem or doing a job is not a difficult undertaking. The trouble we get into is generally caused by no plans or incomplete plans. All plans have some merit.

2-2. Your first step in planning for an installation is to get the information which is on the Local Communications Service Order. From the service order, you can obtain such information as the type of service requested, the location of the installation, and the number of the pair which has been assigned for the installation. After this information has been obtained, the assigned pair or circuit should be tested with the test board. You should go out and talk with the subscriber to determine the desired location of the subset and if there are any unusual activities that would

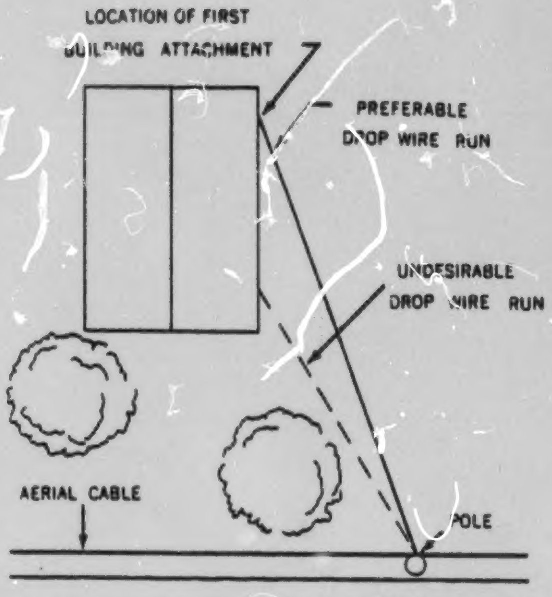


Figure 4. Avoiding tree by selection of building attachment.

affect the installation. It is also important to look for conditions that may affect the completed installation at a later date, such as the use of cranes or booms within the area, planned building expansion, and temporary buildings or partitions.

2-3. After obtaining the basic information, you are ready to plan the routes for the outside and inside wire runs and the approximate location of the building entrance hole. To be effective, your plan must take into consideration such factors as wire clearances, protection requirements, and the equipment and materials needed.

2-4. **Wire Clearances.** In planning the telephone installation, you must consider wire clearances. Clearance specifications for outside wire runs consist of the vertical distance between the ground level and the lowest point in the wire span, and the separation between the telephone wiring and existing objects or other services. Inside wire runs also require specific separation from foreign obstacles unless certain mechanical protection is used. The Air Force has accepted the various wire clearance specifications established by the National Electric Code. You must comply with them to insure safe, trouble-free installations. Required clearances that affect an installation are contained in Air Force publications. Consult these publications whenever a clearance specification is required.

2-5. The outside installation, which normally includes the drop wire and the necessary attachment hardware, must combine a good appearance with safety; that is, the installation must not endanger people or property. Safety is of prime importance when placing drop wire near other wires or points from which the clearance is specified.

2-6. In planning the drop wire run, you must consider its appearance and decide whether or not the installation might cause accidents. For example, the drop should not run over areas where future building work is expected, and it should be kept away from window fronts. If the wire will pass too close to existing objects or through tree branches, plan a route for the wire which will provide the proper clearance. This may be done as illustrated in figures 4, 5, and 6.

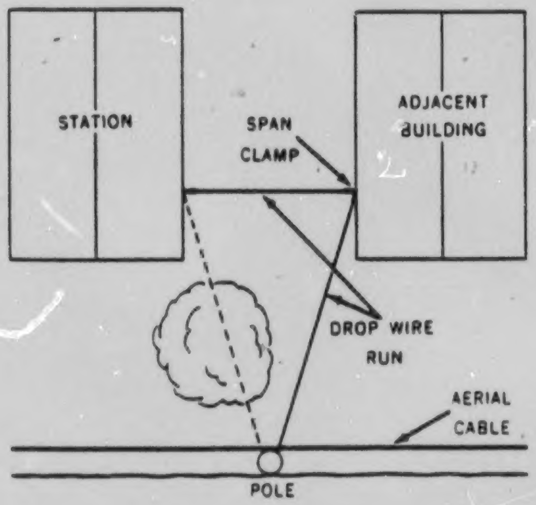


Figure 5. Avoiding tree by use of span clamp.

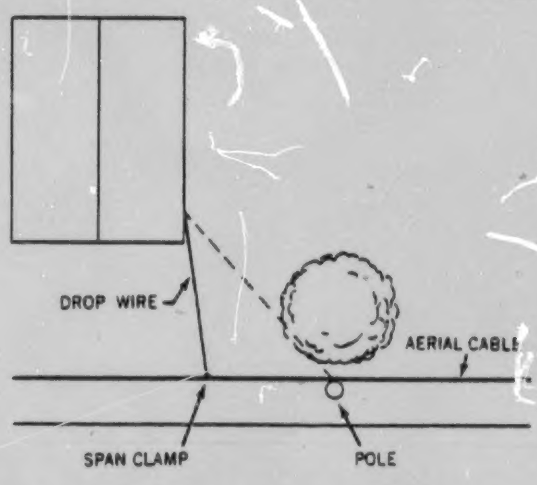


Figure 6. Avoiding tree by use of additional attachment.

2-7. In figure 4, a tree has been avoided by the location selected for the first building attachment. In figure 5, a tree has been avoided by attaching the drop to an adjacent building. Furthermore, in figure 6, a tree has been avoided by using a span clamp to attach the drop wire to the aerial cable. In planning an installation many features, such as those illustrated in figures 4, 5, and 6, can be used to provide the proper wire clearance.

2-8. When the drop wire must pass under the sloping part of a roof, plan on placing the first attachment (the first fastening of the wire to the building) as near the eaves as possible. Also make sure that this attachment will avoid making a swinging contact between the telephone wire and any electrical service or radio wiring. The appearance of the drop wire on the building and the requirement for saving material dictate that the wire run should be made according to standard practices.

2-9. **Protection Requirements.** The protection requirements for a station must also be considered when planning its installation. The station protector shields the station apparatus (telephone sets and auxiliary equipment) against abnormal surges of current and voltages from power lines and lightning. Long aerial telephone circuits are particularly subject to these abnormal surges. If protectors are not used on exposed telephone circuits, the equipment may be damaged and persons using the equipment may be injured. Underground cables which have no connection to aerial wiring are so well shielded that lightning has practically no effect on them.

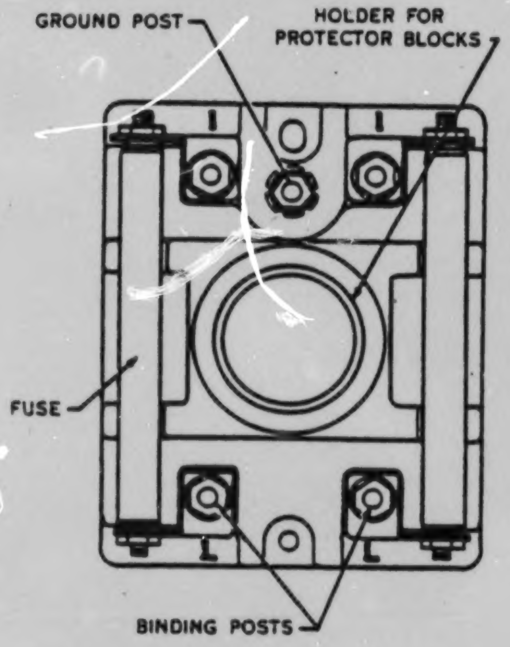


Figure 7. Typical station protector, fused type.

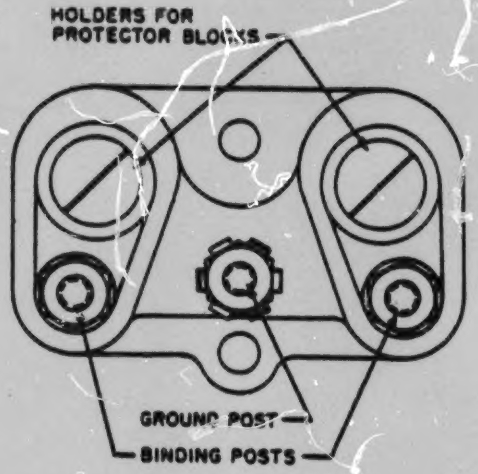


Figure 8. Typical fuseless station protector.

2-10. When planning the protection requirements, the following rule may be used in determining the need for protectors. A station protector must be installed at all aerial drop and block wire installations unless the following conditions apply:

- The service order specifies that a station protector is not required.
- No exposure will be introduced by the drop or block wire installation.

NOTE: A drop or block wire is considered to be exposed under the following conditions: (1) when the wire crosses or parallels below power lines operating at 300 or more volts, (2) when the wire bridges or connects to an open wire circuit, and (3) when the wire bridges or connects to an exposed cable.

2-11. All telephone circuits involving aerial cable or open wire are generally classified as exposed. Therefore, as a general rule, protectors are used with all installations connected to aerial plant facilities.

2-12. There are two general types of station protectors: fused and fuseless. The fuses in the fused protector operate from excessive discharge current; they disconnect the station equipment from the line. The fuseless protector circuit has power contacts that are maintained long enough to cause either the protective devices to remove the equipment from the line or the drop wire or terminal cable to fail before the station is damaged. The design of each type varies slightly, depending upon the manufacturer. The fused type,

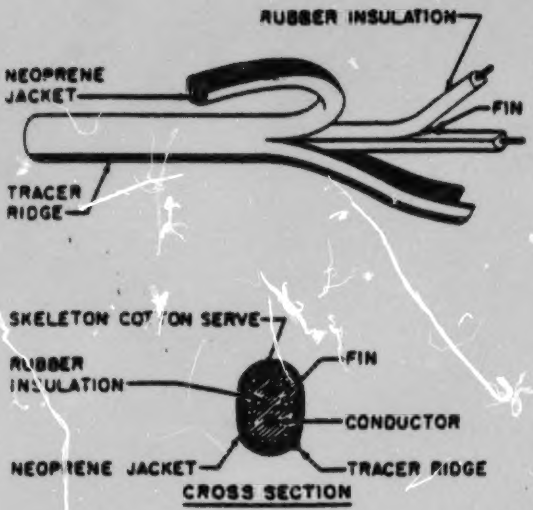

RUBBER INSULATION
NEOPRENE JACKET
FIN
TRACER RIDGE
SKELETON COTTON SERVE
RUBBER INSULATION
FIN
CONDUCTOR
NEOPRENE JACKET
TRACER RIDGE
CROSS SECTION

Figure 9. Parallel drop wire, jacketed.

shown in figure 7, is generally used in conjunction with aerial drop and block wire runs. The fuseless type protector, shown in figure 8, may be used only at stations served directly from grounded sheath cable. Both types of protectors have carbon blocks separated by a slight airgap. One side of the airgap is connected to the drop wire circuit and the other side is connected to ground. Excessive voltages, such as those caused by lightning, jump across this airgap to ground, limiting the peak voltage applied to the station equipment and wiring.

2-13. **Material Requirements for Outside Wire Runs.** When planning an installation, you must also consider the material requirements for the job. You must make sure that your plan includes the proper tools, wire, building attachments, and anchoring devices necessary to complete the installation. The normal drop and block wire installation can be accomplished with the regular installer tools plus any special tools which may sometimes be required. The materials, however, may vary from job to job. In selecting wire for outside runs, you normally have three types to choose from: parallel drop, twisted pair block, and twisted pair bridle. A good installation uses the type of wire designed to do the job.

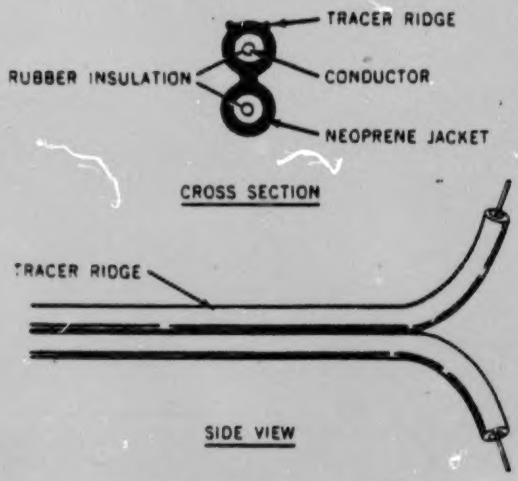

TRACER RIDGE
RUBBER INSULATION
CONDUCTOR
NEOPRENE JACKET
CROSS SECTION
TRACER RIDGE
SIDE VIEW

Figure 10. Parallel drop wire, dumbbell.

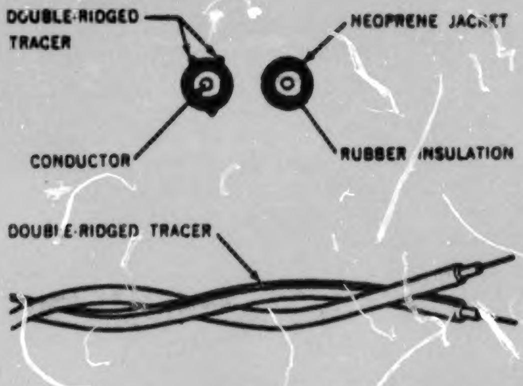

DOUBLE-RIDGED TRACER
NEOPRENE JACKET
CONDUCTOR
RUBBER INSULATION
DOUBLE-RIDGED TRACER

Figure 11. Twisted pair, block wire.

2-14. Parallel drop wire is primarily intended for use in span runs. We mean by this statement that it is the portion of the aerial wire that extends from the open wire or cable terminal-can to the first building attachment. Two types of drop wire are illustrated in figures 9 and 10. The jacketed parallel drop wire shown in figure 9 is the most common type used in new installations. The dumbbell type shown in figure 10 may be found already installed at many established bases. In figure 9, the tracer ridge on the neoprene jacket always identifies the ring wire. The cotton serve adds strength to the drop wire. The fin between the two insulated conductors prevents them from shifting within the jacket; yet makes it easier to separate the individual wires. Parallel drop wire may also be used on building runs to avoid the necessity for splicing. For economy and ease of handling, however, twisted pair block wire is preferred for use on building runs (the portion of the drop or block wire extending between the first building attachment

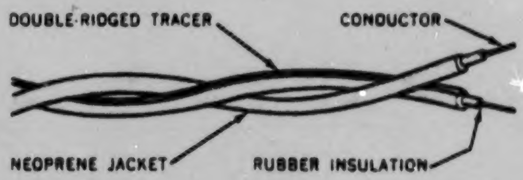

DOUBLE-RIDGED TRACER
CONDUCTOR
NEOPRENE JACKET
RUBBER INSULATION

Figure 12. Twisted pair, bridle wire.

and the station protector). Twisted pair block wire is also used as an inside duct wire where extreme moisture is present. It is normally not used in span runs, and only in the building-to-building spans if the length is less than 35 feet.

2-15. Twisted pair bridle wire should be used for connecting open wire circuits to pole-mounted drop wire and cable terminals; it is not used, however, in span or building runs. Twisted pair, block wire, and twisted pair, bridle wire, are illustrated in figures 11 and 12, respectively. The difference between the two is not readily noticeable. The conductor in the twisted pair block wire is No. 20 gauge (0.0319-inch) copper, copper-steel or bronze, whereas the conductor in the twisted pair bridle wire is No. 14 gauge (0.0640-inch) annealed copper. Twenty gauge block wire is used for the normal subscriber telephone lines, whereas the 14 gauge bridle wire is used for toll line and teletype circuits.

2-16. There are various types and kinds of building attachments and anchoring devices for supporting drop and block wire runs. Just as with wire, these attachments are designed for specific uses. The following conditions are to be considered when selecting attachments:

- The number of wires to be supported.
- The building surface (frame, brick, masonry) on which the wires are to be installed.
- The storm loading district. (The load placed upon a pole line by the wind and ice in combination with the weight of the line components.)
- Whether the installation is exposed or unexposed.

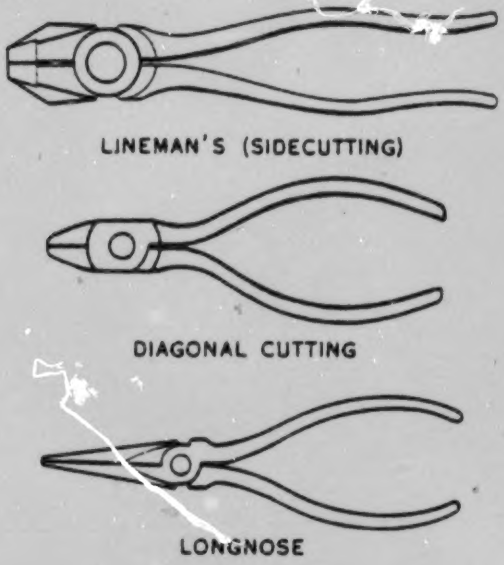


Figure 13. Pliers.

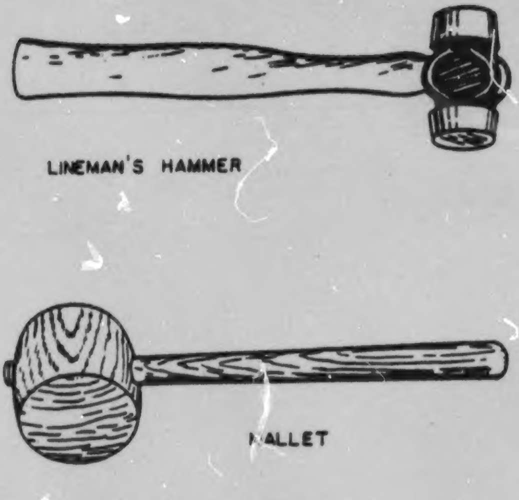


Figure 14. Hammers.

NOTE: All exposed building runs should be insulated from flammable or conducting surfaces. In other words, support the wire so that it does not make contact with the building.

2-17. Types of building attachments are listed in pertinent Air Force publications. Also, many of the attachments are illustrated in Chapter 2 of this publication.

2-18. **Material Requirements for Inside Wire Runs.** The materials and equipment needed for placing inside (station) wiring is usually determined by the wiring facilities already available. Many large, modern buildings are constructed with conduit systems that carry the inside wiring. In planning an installation of this type, the approach is to obtain a drawing of the conduit system. The drawing should indicate the type of conduit, the duct routing or runs, and the location of the outlets. For buildings without existing wiring systems you must, of course, plan the inside wiring system and determine the required materials.

2-19. Three types of wire are generally used for station wiring: plastic-jacketed station wire, block wire, and cross-connecting wire. Plastic-jacketed station wire is normally used for all station wiring except where the runs are close to heating ducts, furnaces, or other locations where temperatures might exceed 212° Fahrenheit. Also, plastic-jacketed wire should not be used where there is exposure to extreme moisture. Block wire should be used where the wire will be exposed to either extreme heat or moisture or where the wiring extends outside the building to outdoor telephone sets or extension ringers. The attachments for supporting inside wire are also illustrated in Chapter 2 of this volume.

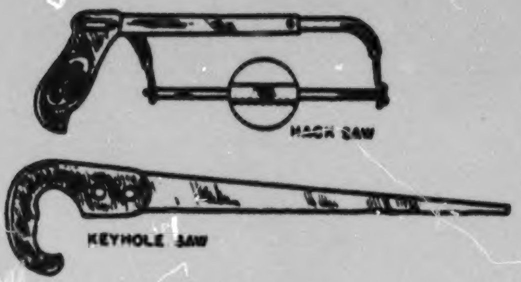


Figure 15. Saws.

2-20. After your preliminary plans are complete for the wire runs, recheck and make certain that all parts of your plan fit together. You may find it necessary to revise your proposed wire routes because of clearance and separation requirements, insulating problems, type of building construction, or other obstacles. Remember, a little more time spent in planning any work results in fewer problems and less time spent in completing the job.

2-21. Up to this point, general areas that the installer should consider in planning an installation have been explained. To help you apply these requirements to an actual installation, the details for installing a telephone station will be covered later in this publication. Before we discuss the installation, however, we wish to briefly acquaint you with installer tools, soldering, and pole climbing.

3. Tools and Work Practices

3-1. Many and various types of tools are used by outside plant personnel. In comparison with those used by the cable splicers and outside wire and antenna specialists, relatively few tools are required by the installer. Good tools and equipment, however, are essential to the performance of installation and maintenance work of any kind. Without proper tools, it would be impossible for the installer-repairman to install and maintain telephone substations. Furthermore, without proper tools and knowledge of how to use and care for them, the installer will waste his time and may injure himself or some of his fellow workmen.

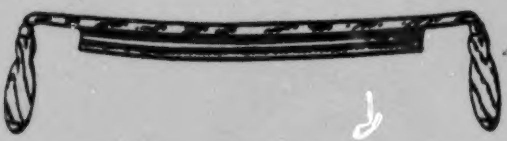


Figure 16. Draw knife.

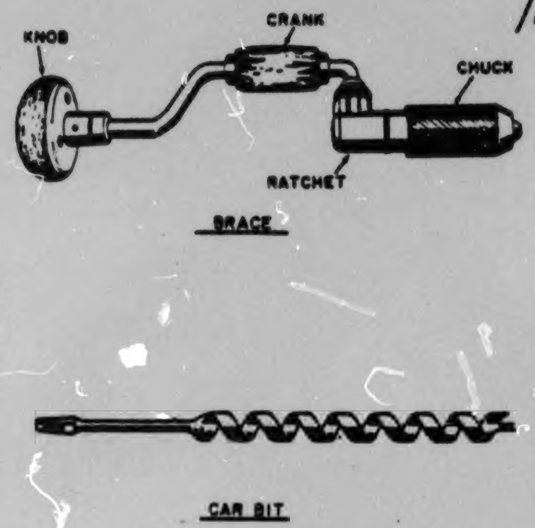


Figure 17. Brace and bit.

3-2. Although it may not seem important at the moment, the proper selection and use of tools is a part of every installation or repair job. In fact, learning to select and use tools in the proper manner is probably the most important part of learning the job. Before you can select the tools for performing a given job, you must know what tools and equipment are normally available. The tools used by the installer-repairman are covered in technical orders on outside plant construction (TO's of the 31-10 series).

3-3. To learn how to use tools of any kind is mostly a matter of practice. Anything that could be written here would not teach you to be proficient in the use of installer-repairman tools. The only way in which you may become proficient in using tools of the trade is by practicing their use under the guidance of a well-qualified technician. To help you in getting started with installer-repairman tools, the following information is given for a few tools of the trade.

3-4. **Pliers.** Three types of pliers which are used by the installer-repairman are illustrated in figure 13. These types are the lineman's pliers, the diagonal pliers, and the long-nose pliers. The

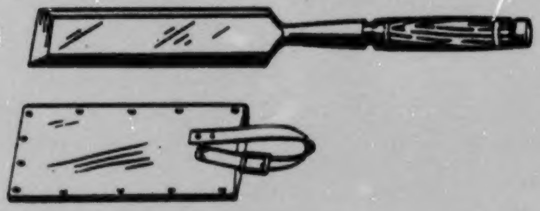


Figure 18. Wood chisel with blade guard.

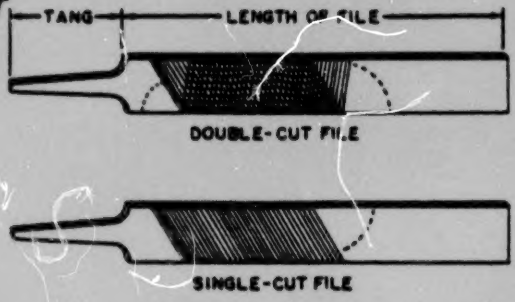


Figure 19. Files.

lineman's pliers are side-cutting pliers with blunt jaws, having a scored gripping surface at the front and cutting edges on the side. They are used for cutting wire, for nicking solid wire for breaking, for holding wire for bending and twisting, and for crushing and stripping insulation. The diagonal pliers, with cutting jaws set at an angle of about 15° with the handle, are used by the installer-repairman for cutting small wires. The long-nose pliers have long, slender jaws, flat on the inside with scored gripping surfaces near the tip end. They are used in holding and bending wires for attachment to terminal lugs and for gripping small objects not accessible to the fingers.

3-5. Pliers should be used only to do work for which they are designed. They should not be used in place of a wrench as this will damage both the pliers and the equipment. Never force pliers beyond their capacity and don't cut steel wire or hard rivets with diagonal or lineman's pliers.

3-6. **Hammers.** Figure 14 illustrates a lineman's hammer and a wooden mallet. The lineman's hammer is approximately 15 inches long and has a 2-pound, double-faced head with a wooden handle. It is used for driving lag screws and thru-bolts, and on heavy line work which requires an accurate, heavy-duty hammer. The wooden mallet is used for driving and forming operations on tools or materials which might easily be damaged by blows from a metal-faced hammer.

3-7. When using the hammer, it should be held near the end of the handle with its face paralleled to the work. A grip just tight enough to control the blow is best. Raise the arm straightaway from the object to be struck and then bring the hammer down on it with a quick, sharp motion. Practice is the only means by which you can learn to use the hammer properly.

3-8. Most accidents with hammers are caused either by using them improperly or by using a hammer when its head is loose on the handle. When the head is loose on the handle, it is likely to fly off and hit you or someone else who may be in the area. Also, if your hands are oily or greasy, the hammer may slip, damaging the work or injuring you or your fellow workmen.

3-9. **Saws.** Figure 15 illustrates a hacksaw and a keyhole saw. The hacksaw is used by the installer to cut pieces of metal, tubing, etc. Its frame is normally adjustable to use blades from 8 to 16 inches in length. The points of the teeth on the blade should point away from the handle when the blade is properly attached to the frame. With the blade inserted in the frame in this manner, the sawing should be done by moving the saw forward with a light, steady stroke. At the end of the stroke, relieve the pressure and draw the blade straight back, making no cut on the back stroke.

3-10. Hacksaw blades are normally provided with 14 to 32 teeth per inch. Blades with 14 teeth per inch should be used on heavier materials where the coarse pitch of the teeth makes the saw free and fast cutting. The blades with a greater number of teeth are used on thinner material. For example, a blade with 32 teeth per inch is used on thin-wall tubing, conduit, and on sheet metal thinner than 18 gage.

3-11. The keyhole saw has a tapered blade and is used to cut along a curved line, and to start a cut for a larger saw.

3-12. **Draw Knife.** The draw knife, illustrated in figure 16, is a very important tool to outside plant personnel. It is used to smooth poles, remove gaff marks, and to shave away excess wood. It has a single-bevel, knife-edged, steel blade and is approximately 1½ inches wide and

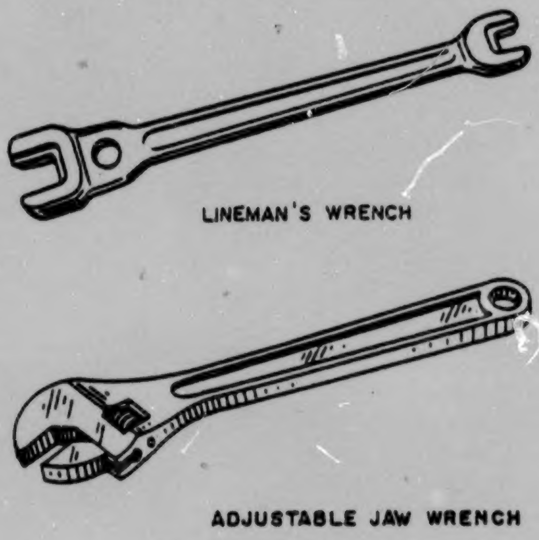


Figure 20. Wrenches.

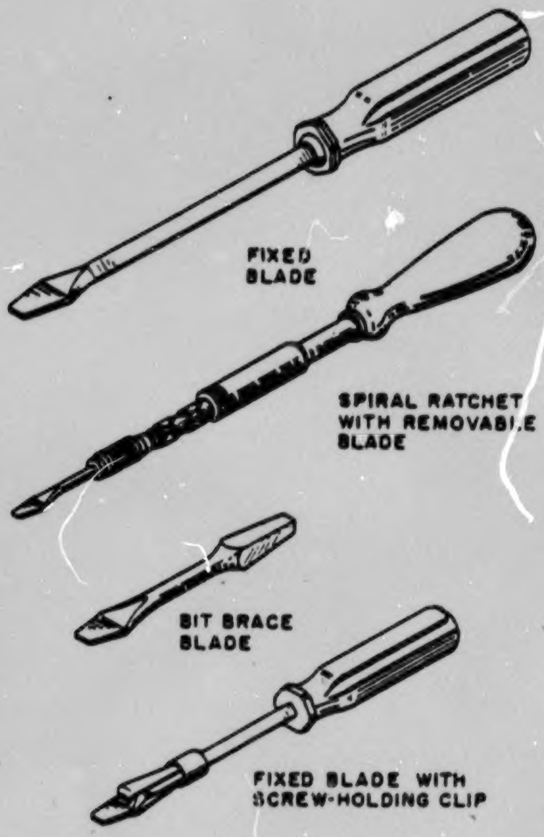

FIXED BLADE
SPIRAL RATCHET WITH REMOVABLE BLADE
BIT BRACE BLADE
FIXED BLADE WITH SCREW-HOLDING CLIP

Figure 21. Screwdrivers.

12 inches long. It has wooden handles at each end and at right angles to the blade.

3-13. **Brace and Bit.** The brace and bit, illustrated in figure 17, is representative of the drills used by the installer-repairman. Many types of bits, up to 24-inch lengths, are used by the installer to drill holes in walls, floors, etc. Care must be taken in using the drill to prevent damage to the head and cutter point. Also, care should be taken not to drill into electrical wiring or other facilities.

3-14. The brace illustrated can be used with any of several bits. The round cap permits pressure to be applied as support is given to the brace when holes are being drilled in wood.

3-15. **Wood Chisel.** The wood chisel with its blade guard is illustrated in figure 18. The chisel shown has a single-edged, steel, 2-inch cutting blade with a wooden handle. This chisel is used to remove chips or sections of wood in framing poles. These materials may be removed by hand pressure or by striking the end of the chisel handle with a wooden mallet.

3-16. **Files.** Files are used for cutting, smoothing, or removing small amounts of metal. They vary in length, shape, and in the cut of the teeth, providing files for various purposes. As illustrated in figure 19, the file may be of either a single-cut or double-cut type. Wooden handles, which slip over the tang, are provided to protect the hands of anyone using the file. It is dangerous to use a file without a handle as the end of the tang is usually rather sharp. As an installer-repairman, you will need files in touching up your climber gaffs and in sharpening and maintaining your other tools.

3-17. **Wrenches.** The wrenches illustrated in figure 20 are representative of those used by outside plant personnel. The adjustable wrench is a general-purpose tool and is used for holding or turning nuts and bolts. The lineman's wrench is an open-end wrench with two openings of different size at the ends. It is used on carriage bolts, lag screws, crossarms bolts, and 3-bolt guy clamps. A hole at the larger end is used in tightening or turning in pole steps. The most important rule in using a wrench of any kind is to make certain that it is of proper size so that its jaws fit the nut or bolt properly.

3-18. The best way to tighten a nut with a wrench is to turn it until it has a firm, solid

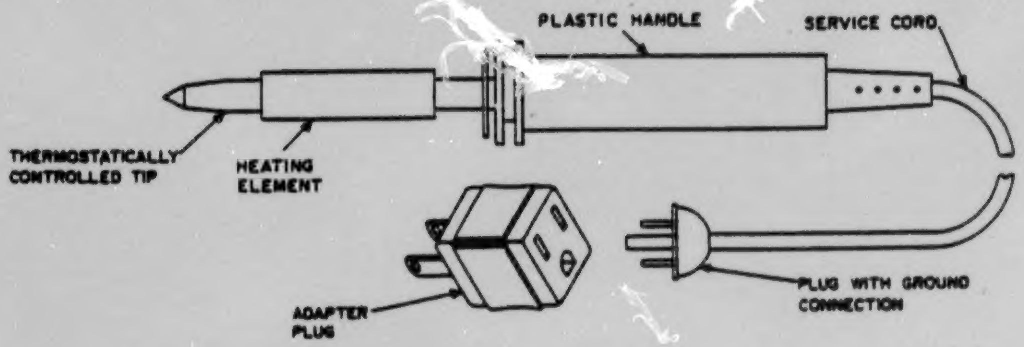


Figure 22. Electric soldering iron.

"feel." This will turn the nut to its proper tightness without stripping the threads or twisting off the bolt. Experience alone develops this sense of "feel" which will enable you to tighten a nut, stud, or cap-screw to the proper degree. Practice until you know you have mastered this "feel."

3-19. **Screwdrivers.** The screwdriver (see fig. 21) consists of a blade with a tip shaped to fit in the driving slot of a screw, and a shank or tang securely fastened in a driver handle. The fixed-blade screwdriver, consisting of an integral blade and handle, is used as a general-purpose screwdriver for many kinds of screws. It is furnished in various sizes to fit the various screws.

3-20. The ratchet screwdriver, with its blade and handle, provides right- and left-hand ratchet-drive action, or rigid-drive action. The spiral ratchet screwdriver, in which drill bits and other attachments, as well as the screwdriver bits are used, is rotated by pushing on the handle, or is locked to provide rigid action. As illustrated in figure 21, screwdriver bits are also provided for use with the bit brace. In addition, some fixed screwdrivers are provided with a screw-holding clip, as illustrated in figure 21.

3-21. When using screwdrivers, you can avoid most trouble by selecting the right size and kind of screwdriver before you start to work. A screwdriver should be selected which fits the slot in the screwhead, leaving very little play along the sides of the bit. Some play must exist along the sides of the bit, however, to insure that the bit can fully enter the slot. If the bit cannot fully enter the slot, the screwdriver will slip, damaging both the screwhead and the screwdriver.

3-22. The screwdriver was designed to loosen and tighten screws. Don't try to use it as a chisel; you'll only ruin the handle and chip the bit. Don't use a screwdriver as a pry bar. It was not designed for this, and it will only bend or break. Furthermore, never use a screwdriver to short across an electrical circuit. The current may be strong enough to arc and melt the screwdriver blade, and damage the circuit.

3-23. When the point of a screwdriver becomes rounded or broken, it can normally be ground back to its original shape. Don't grind away any more metal than necessary, as you don't want to grind past the hardened part. As the screwdriver blade becomes worn, it can be dressed up and reshaped by using a flat, smooth file.

3-24. **Work Practices.** To understand the planning and accomplishment of work in the installer-repairman area, you must have a knowledge of telephone section procedures. Not only must you be able to plan, install, and maintain telephone substations, but you must also be able to complete forms and records in accordance with established procedures. Since the exact procedures and forms used may vary in different organizations, we will not discuss specific forms or procedures in this publication. We will, however, discuss the need for such records, along with the general procedures. It will be up to you to learn the exact forms and procedures used by the organization to which you are assigned.

3-25. To cover the general practices used in the telephone section, let us assume that an organization on your base has requested that a telephone be installed in one of its buildings. This request, of course, is made to the base communications officer. Before this officer can make any decision with regard to this telephone installation, he must have answers to the following questions:

- Is a wire pair (either cable or open-line) available for the installation?
- Is switching equipment available for connecting this installation at the central office?

3-26. To obtain answers to the above questions, check with the wire records clerk at the central office. This clerk maintains cable and wire records which should indicate the availability of all cable pairs and wires on the base. The accuracy of his records, however, may depend to some extent upon reports made by the installer-repairman, that is, reports made on wire or cable pairs used in installation. This points up the need for you to accurately record the numbers of all wire pairs used by you or your crew during installation.

3-27. An answer to the question on the availability of switching equipment will also be found in the central office records. From these wire and office records, several things concerning this proposed telephone installation can be determined. The most important of these are as follows:

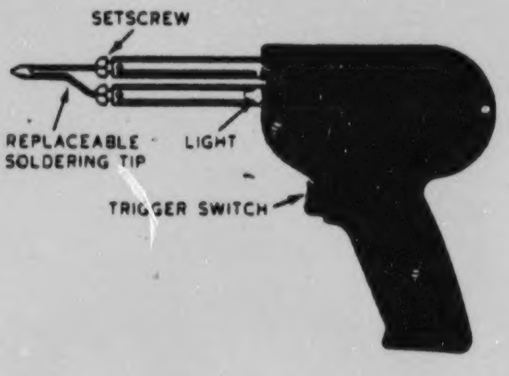


Figure 23. Electric soldering gun.

- Wire pair or circuit availability.
- The type of circuit available (party or private line).
- If party line, the type of ring to be used.

3-28. If the wire pairs and the equipment are available and installation of the telephone is approved, the next step in the work procedures is the issuance of a Local Communications Service Order. When the base communications officer approves the installation, the service order will then be prepared. Copies of the service order are then furnished to the installer-repairman. This service order is of utmost importance to the installer-repairman because it is one piece of paperwork with which he is most directly concerned. The service order is important to the installer-repairman in the following ways:

- It gives him the authority for doing the job. In other words, it is his order to do the job.
- It gives him the authority for obtaining the necessary parts and equipment for completing the work. As a matter of fact, he must use the communications service order to draw the needed parts and equipment from his source of supply.
- It furnishes the installer with such information as the location of the job, the work to be done, the wire or cable pairs involved, the telephone number, and the type of service.

3-29. To continue with our assumed installation, let us return to the point of receiving the Local Communications Service Order. When you receive a Local Communications Service Order directing the installation of a telephone, you should then plan the installation, as mentioned earlier in this chapter. After your planning is completed, you should then draw the needed materials and equipment for completing the job. Of course, the materials drawn must be recorded on the service order or on some sort of materials record. After the planning has been completed and the materials have been drawn, you can then proceed with the job.

3-30. While making a telephone installation, the installer-repairman must record numerous items. First of all, the man-hours spent on the job and the materials used must all be reported. Secondly, as the job is completed, the wire or cable pair used, the pole number, and any other pertinent information must be recorded on the Local Communications Service Order. It is important that you do this most accurately to assist the telephone office in keeping good records.

3-31. After the installation work has been completed, you must then complete and sign the service order. Before you do this, however, you should turn in any excess material that was not used, making sure that you receive credit for it. Also, you should make sure that the service order is complete in every detail before you turn it in as completed. You should remember that information recorded on this service order has a lot to do with future operation. First of all, information extracted from the completed service orders helps the telephone office in maintaining accurate records. Secondly, information, such as materials used, is extracted from service orders for data processing by the Air Force.

3-32. It should be noted at this time that the truck used by the installer-repairman, at some installations, may be kept fully stocked with installation materials. In this case, the installer does all of his installation planning on the job and also keeps a record of all materials used. Furthermore, he must see that his truck is restocked daily.

4. Soldering and Splicing

4-1. The installer-repairman must know soldering and splicing as they apply to telephone installation. This section contains information which will provide you with some basic knowledge of soldering and splicing procedures. To become proficient, however, you must practice soldering and splicing as often as you have time.

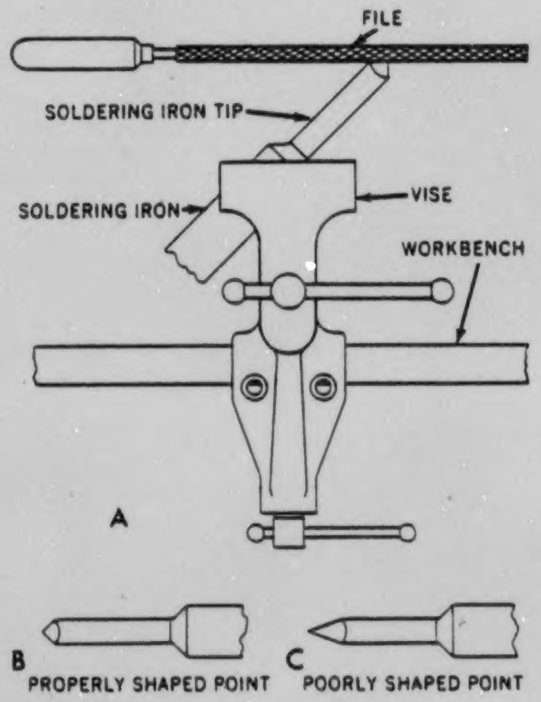


Figure 24. Filing the tip of a soldering iron.

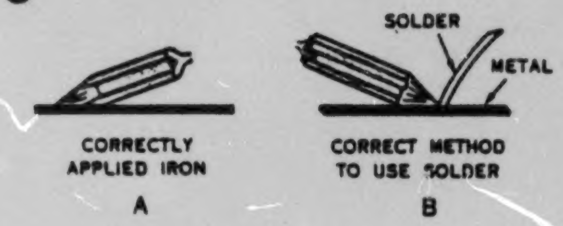


Figure 25. Flow method of applying solder.

4-2. The wiring for a telephone system must be solid and strong enough to stand for the period it is to be used. It is easy to neglect details of installation which can result in equipment failure. Splices are designed for permanent connection; therefore, they must be mechanically strong and electrically perfect. If they are not, they often become a source of telephone circuit trouble. Every installer-repairman should be able to splice and solder telephone wiring and connections.

4-3. **Soldering Equipment.** Soldering is the heating of a fusible alloy until it melts and incloses the contacting surfaces of two or more metals to be joined. When this combination (metals and solder) cools, it hardens to bind all the elements tightly together. When wire connections are not soldered, the oxygen in the air combines with the surface of the metal, forming a corrosion. This corrosion of connections offers additional electrical resistance to the circuit. If a connection is properly soldered, the oxygen of the air cannot combine with the surface of the metal; thus, corrosion of the connection is prevented. A soldered connection maintains good contact and, at the same time, does not loosen readily from vibration.

4-4. *Solder.* Various types of solder, soldering paste, and flux are furnished by manufacturers for different kinds of soldering work. For telephone and electrical wiring, it is best to use a rosin core solder which is made in the shape of a wire and is rolled up on a metal spool. The center of this wirelike solder is hollow and it is filled with a rosin paste, which is proper for electrical work. Other types of solder should not be used on electrical connections as they may do more harm than good. This is so especially with acid-core solder, because it will cause corrosion in electrical circuits. To solder a connection, it is necessary to heat the solder to its melting point. This is usually done with a soldering iron or a gun of some sort.

4-5. *Electric soldering irons.* The electric soldering iron, illustrated in figure 22, is used for light soldering. In addition to having the normal soldering tip, shank, and handle, this iron is equipped with an electrical heating element. This element is attached to an electric outlet by a cord and plug. One big advantage of electric soldering irons over the conventional types (units heated by torches, etc.) is that the electric iron provides a more constant temperature at the tip. With many electric soldering irons, the tip temperature is thermostatically controlled to insure a uniform soldering temperature.

4-6. *Electric soldering guns.* The electric soldering gun, shown in figure 23, is very handy for working in small, hard-to-get-at places. It has a pistol grip and trigger switch, plus a pilot lamp which lights the area to be soldered. Soldering guns are used with 115-volt 60-cycle alternating current, as are most of the electric soldering irons. The soldering gun is excellent for soldering wiring connections because of its fast heating rate. Many of these guns heat to soldering temperature in 10 to 15 seconds.

4-7. *Nonelectric soldering irons.* This type of soldering iron is to be used primarily in emergencies where power is not available. It takes about 30 seconds for the chemically charged cartridge within the tip chamber to heat the copper tip, and the heat is maintained for a maximum of about 7 minutes. The cartridge is activated when a firing pin is released at the rear of the handle.

4-8. *Soldering coppers.* Soldering coppers are heated by external means, using a gasoline blowtorch, an alcohol torch, or a gas burner. The copper tip is not removable so different-sized coppers are used for the various kinds of work. The disadvantages of these devices are (1) they must be continually reheated, and (2) they frequently become overheated, causing the tip to become pitted and rough. This type of "iron" is used for heavy soldering jobs, but is not too satisfactory for use on wiring connections.

4-9. **Fundamentals of Soldering.** Basically, a

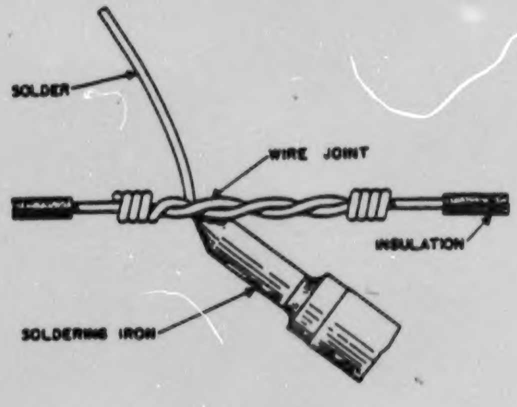


Figure 26. Soldering a spliced joint.

conductor is soldered by first cleaning and tinning the soldering iron and conductor, and then by heating the conductor, while applying solder to form the connection.

4-10. *Tinning the iron.* Good soldering is possible only if the tip of the iron is in good condition. Good condition means that the tip of the iron must be smooth, of proper shape, and covered with a thin coat of solder on its working surface. The cleaning and shaping of the tip along with the application of a thin coat of solder is referred to as "tinning the iron."

4-11. The soldering iron tip is cleaned and shaped by removing the pits, old solder, and tarnished areas with a medium grade file. To do this, you should heat the iron and place it in a vise or holding clamp, as shown in figure 24,A. With electric irons, grip only the tip of the iron to avoid damage to the heating element. If only one surface of the tip is to be tinned, file only that surface. Note that the section of the tip to be tinned is parallel to the top of the vise. When filing the tip, be careful not to cut away any more of the tip than necessary. Remove only the pits and tarnished areas, leaving a smooth, flat surface. After the filing has been done, touch the rosin-core solder to the filed side of the heated tip. The solder should flow readily over the bare area to cover it with a smooth, thin coating. Wipe off any excess solder with a damp, clean cloth. B and C of figure 24 show, respectively, a properly shaped point and a poorly shaped point.

4-12. *Tinning the conductor.* The surface of the conductor must be cleaned before solder is applied; otherwise, corrosion will take place un-

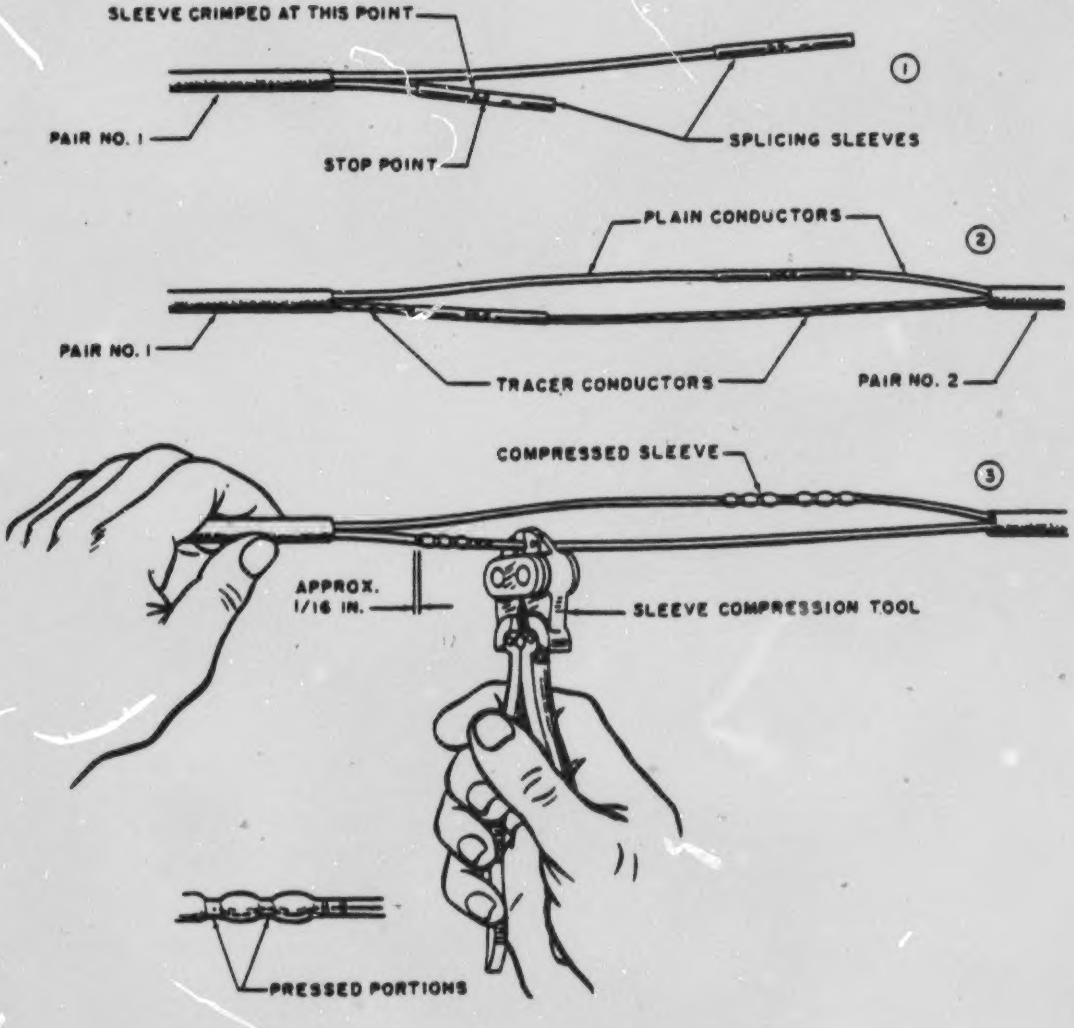

SLEEVE CRIMPED AT THIS POINT
①
PAIR NO. 1
STOP POINT
SPLICING SLEEVES
PLAIN CONDUCTORS
②
PAIR NO. 1
TRACER CONDUCTORS
PAIR NO. 2
COMPRESSED SLEEVE
③
APPROX. 1/16 IN.
SLEEVE COMPRESSION TOOL
PRESSED PORTIONS

Figure 27. Placing and crimping copper sleeves.

der the layer of solder. This may cause the joint to break, or it may be a possible source of loss in voltage. A conductor is not properly tinned until it is thoroughly cleaned and then covered with a thin coat of solder. It is usually cleaned by using either wire strippers, pliers, a file, or a knife. In any case, the conductor must have a smooth, bright surface, free of any nicks or cuts. After it has been cleaned, the surface can be covered with a thin coat of solder by using the soldering iron.

4-13. *The soldering process.* After the iron and the materials have been cleaned, the soldering can then be done. In telephone work, there are two commonly used methods of applying solder: the "flow" method and the "sweat" method. When the "flow" method is used, the tinned area of the soldering iron tip is placed on the surface of the metal, as shown in figure 25. After the materials forming the joint are heated, the solder is held against the joint until it melts and flows freely. This procedure is preferred in the telephone field for most of the soldering work because it is faster, uses less heat, and provides for tighter connections with the use of less solder.

4-14. The "sweat" method of applying solder is performed by placing the tip of the iron under the metals and the solder to the top of the metals, as shown in figure 26. As soon as the metals are hot enough to melt the solder, the flowing solder will surround them and make the desired bond. This latter method of soldering is preferred when splicing telephone wires.

4-15. With either of the soldering methods, excessive heat will cause the solder to flow away from the joint and along the conductors, and thus results in loose connections and possible short circuits. Insufficient heat to the metals leaves a large ball of solder and a weak joint. The correct heating point is reached when the free-flowing solder begins to tarnish.

4-16. After the joint has been made, the iron should be removed from contact with the metals gradually to prevent defects in the newly made joint. After removal of the iron, the connection should not be moved for a few seconds in order that it may cool and seal correctly.

4-17. **Wire Splices.** A splice is often required when installing drop wires and ground rods. The preferred method of splicing is performed with splicing sleeves and sleeve compression tools. As you can see in (1) and (2) of figure 27, the sleeves are placed over the wires where they are to be joined and then compressed with a sleeve compression tool, as shown in (3) of figure 27. The sleeves are staggered, as shown in the illustration, to eliminate the possibility of a short between the sleeves. After the sleeves are compressed, each one is then taped individually, and then the entire joint is covered with tape. When making a splice of this type, sleeves must be selected that fit the wire with the insulation removed. Sleeves are furnished in numerous sizes to fit the commonly used wiring. Also, sleeves are furnished which will join wires of different sizes—that is, a larger wire to a smaller wire.

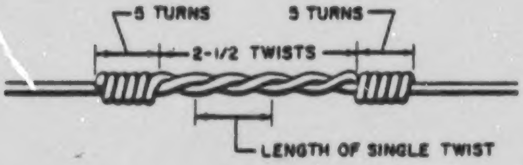


Figure 28. Wire splice.

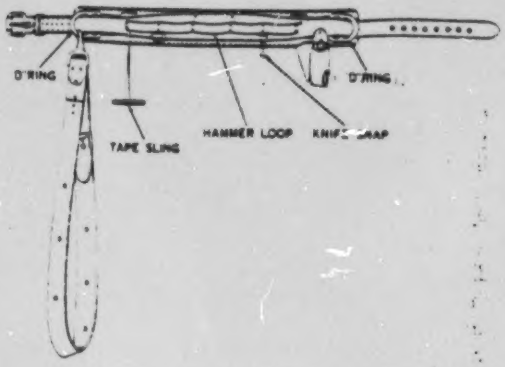


Figure 29. Lineman's body belt with safety strap.

4-18. Emergency splices may be made in the wiring by twisting the conductors, as shown in figure 28. Before twisting the wires, however, they should be cleaned in readiness for soldering. After twisting the splices, as shown in figure 28, they are then soldered and taped to complete the splice. This type of splice, when used on wire pairs, is staggered in the same manner as when compression sleeves are used.

5. Pole Climbing Equipment and Principles

5-1. The installer-repairman must be able to climb telephone poles in order to do his work. The installation of a telephone subset may require the installer to climb a telephone pole with climbers. For this reason, the installer must have a knowledge of pole climbing and pole climbing equipment. This section describes the equipment used in pole climbing and explains some of the principles involved.

5-2. To climb poles, the installer uses the same type of climbing equipment as the lineman does. Basically, this equipment consists of two items: the lineman's body belt with safety strap and the lineman's climbers.

5-3. **Body Belt with Safety Strap.** The lineman's belt and safety strap are made of high-grade leather. They are sewed with hot waxed linen thread and are also riveted. Figure 29 shows a body belt which is used currently by the Air Force. The body belt is obtained according to size. The actual belt measurement is the snug distance between the heels or straight ends of the two D-rings. Most outside plant supply sections provide belts which range in sizes from D-18 through D-30. The body belt is worn over the hips and tightened just enough to prevent slipping. A belt of the proper size permits the D-rings to rest just behind the projecting portions of the hip bones. Figure 30 illustrates the belt's position while the lineman is on the ground. For safety reasons, do not punch additional holes in the body belt. If your belt does not fit properly, you should try one of a different size.

5-4. Safety straps are adjustable to various lengths, ranging from 60 through 90 inches. A right-handed man should snap both ends of the safety strap to the left side D-ring when the strap is not in use. A left-handed man should snap both ends to the right side D-ring. The end of the strap, which is doubled to permit adjustments, is snapped to the D-ring with the snap hook keeper toward the rear. The riveted end of the strap is snapped onto the same ring but with the snap hoop keeper facing the front. This arrangement enables the climber to keep the snap at the doubled end of the strap hooked at all times. Figure 30 pictures the hooked safety strap on the body belt of a right-handed lineman.

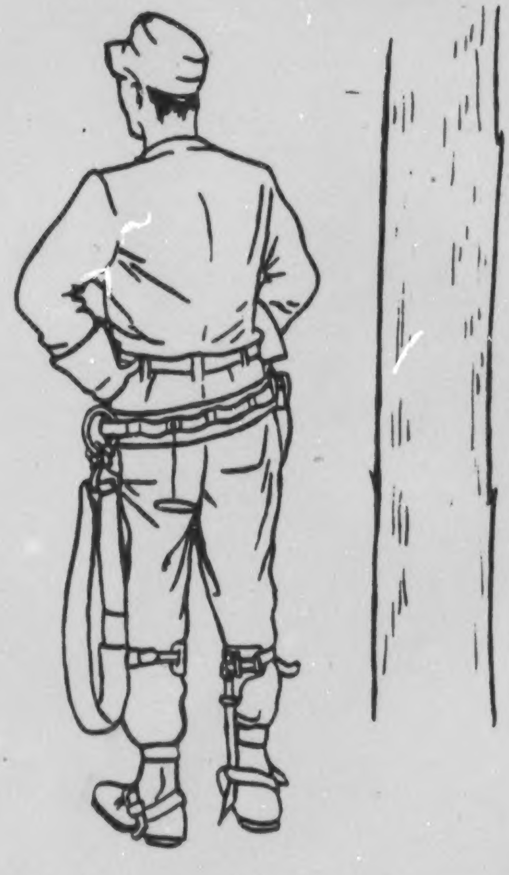


Figure 30. An airman with climbers and body belt.

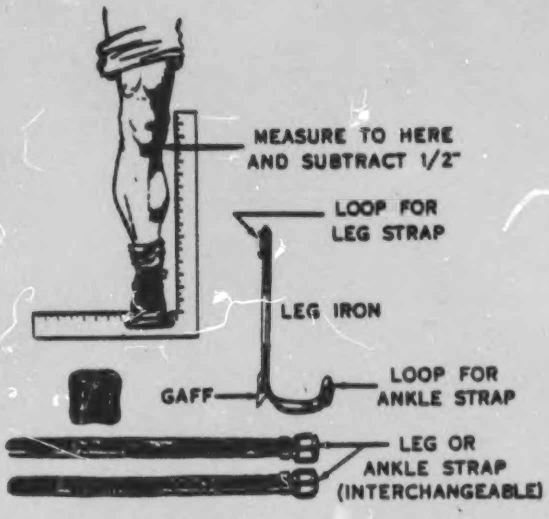


Figure 31. Climber size measurement.

5-5. **Lineman's Climbers.** Climbers are normally used for climbing poles that have no steps and for climbing trees. Tree climbing is not recommended, however, unless you use climber gaffs that are specially made for that purpose.

5-6. Climbers are available in half sizes, ranging from 13 inches to 20 inches, as measured from the bottom of the stirrup to the upper end of the leg iron, which may be bent cold to conform to the wearer's leg. Figure 31 shows climber details and how to determine the correct size. Measure from the bottom of the knee bone to the underside of the shoe at the arch. Then subtract ½ inch from this distance to get the correct climber size.

5-7. **Care of Climbing Equipment.** The body belt, safety straps, and climbers should be inspected thoroughly before they are used. The body belt and safety straps must be inspected for cracks, cuts, loose or broken threads, loose rivets, faulty snap hook keepers, etc. To insure a long life for the body belt, it should be cleaned frequently with either a saddle soap or a "Castile soap." Then to keep the leather soft and pliable, it should be wiped dry and oiled lightly

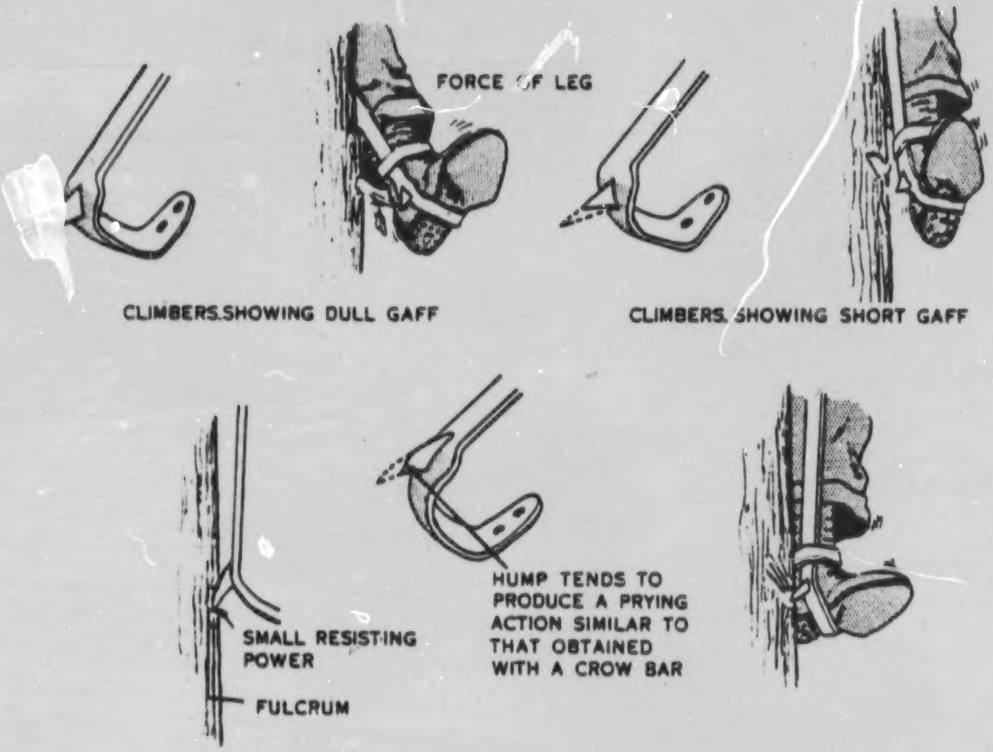

FORCE OF LEG
CLIMBERS SHOWING DULL GAFF
CLIMBERS SHOWING SHORT GAFF
SMALL RESISTING POWER
FULCRUM
HUMP TENDS TO PRODUCE A PRYING ACTION SIMILAR TO THAT OBTAINED WITH A CROW BAR

Figure 32. Dangerous gaff shapes.

with Neat's Foot oil. Never use mineral oil or grease as a preservative. Also, be careful to keep the belt away from excess heat.

5-8. The climbers should be examined for defective straps or pads and for broken, rusty, or loose gaffs. The normal care for leather will preserve the straps and pads. To take care of the gaff, however, will require a little more skill. To get some idea of dangerous gaff shapes, study the illustrations in figure 32. To properly sharpen and care for the gaff requires the use of a gaff gauge, as illustrated in figure 33. This gauge is used in measuring the gaff for length, width, thickness, and other dimensions. Furthermore, this gauge is used when filing the gaff to determine when the proper shape is obtained.

5-9. **Safeguards and Climbing.** To climb poles safely, you must learn to use climbing equipment in the proper manner. To use this equipment safely and effectively, you should follow these precautions:

(1) In placing the safety strap around the pole, make sure that the buckle is securely fastened and that the strap is not twisted.

(2) Before climbing, test the snap hook and D-ring. Never rely solely on the click of the keeper in the snap hook when attaching a safety snap to a D-ring. Make sure that the parts are secure.

(3) Always have the keeper of the snap hook away from the body when the snap hook is fastended in the D-ring.

(4) When working on a ladder, do not fasten the safety strap to the ladder.

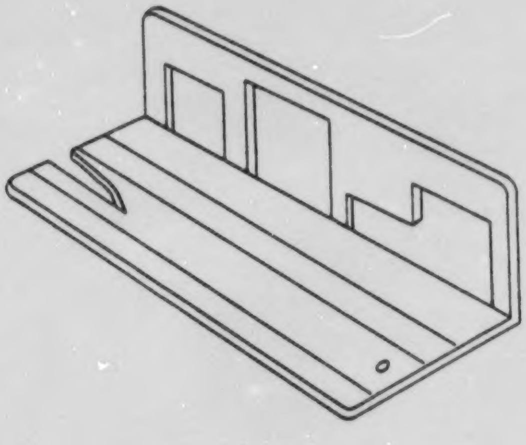


Figure 33. Gaff gauge.

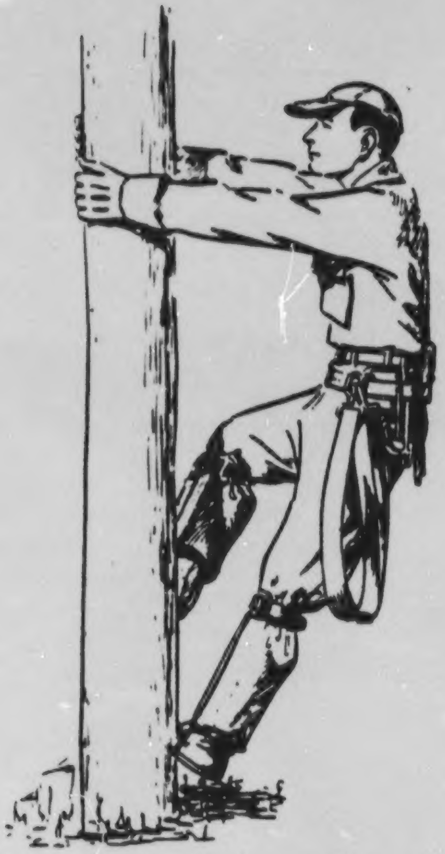


Figure 34. Beginning the climb.

(5) Never punch holes in a body belt or safety strap.

(6) When not using the body belt and the safety strap, snap both ends of the safety strap into one of the D-rings.

(7) Do not place the safety strap around the pole within a foot of the top of the pole.

(8) Never throw or drop a safety strap from a pole.

(9) In general, do not put climbers in the same container with body belt and safety straps; however, if you must, take care to keep the gaffs from punching or cutting the belts or straps.

(10) Use climbers of the correct size.

(11) Never wear climbers on work where they are not needed; that is, do not wear them when working on the ground, on a ladder, or in deep snow.

(12) Frequently inspect climbers to determine the condition of all parts. If the climbers are defective or unsafe, as shown in figure 32, they should be replaced or repaired.

"(13) Gloves and long sleeves should be worn while climbing."

5-10. Using climbers to climb poles is relatively simple as long as you follow these precautions and use the proper techniques. For example, in climbing a pole, keep your arms only slightly bent and your hips farther from the pole than any other part of your body. To stick the climber gaffs into the pole, thrust your legs inward and downward. To pull them out, move them upward and outward. If your body is too close to the pole, your gaffs may cut out of the wood. So check your position by placing your hands on the far side of the pole. If your hands overlap, your body is too close to the pole; the gaffs may break out of the wood and cause you to lose your footing. If your hands reach only the side of the pole, your body is too far away. Then your palms have no grasp and your arms are under a great strain. The weight of the body should be carried normally and should be lifted entirely on the gaffs, with your arms serving only to balance.

5-11. The position of your hips is also important. If they are too close to the pole, your legs will be parallel to the pole and the gaffs will cut

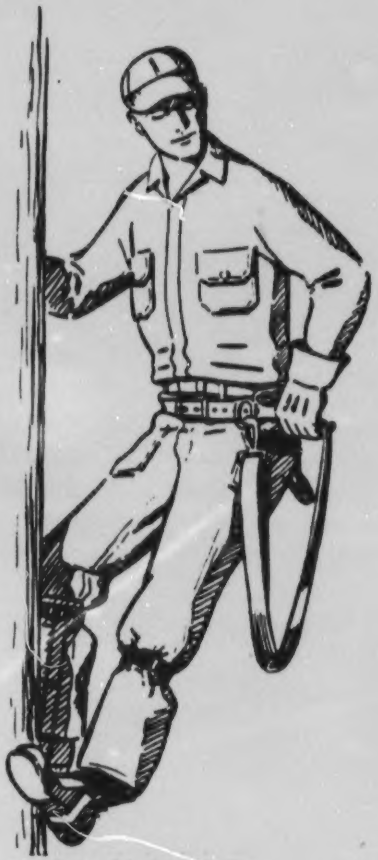


Figure 35. Unhooking safety strap.

out. But if your hips are too far out, the arms are again placed under strain because they will be supporting too much of your weight. If your knees are bent so that they touch the pole, the gaffs will lose purchase and cut out. Note in figure 34 that the lineman keeps his knees and body straight, and as a result, the gaffs are forced into the pole rather than down the pole.

5-12. Another precaution to be taken before climbing is to inspect the pole. Note the location of wide weather cracks and hard or soft spots in the wood. Next, study the equipment on the pole, such as cables, crossarms, or other obstacles that may interfere with climbing. Then see if the pole leans. If so, you should face the direction in which the pole is leaning and climb on the high side. If you suspect that the pole is old, with possible breaks or a soft center, be sure to test it before climbing. Never, under any conditions, climb a weak pole without first adequately reinforcing it.

5-13. To climb, grasp the pole with one hand or with both hands and raise your left foot about 10 inches from the ground, keeping the gaff about 1 inch from the pole. Then, with a downward thrust, jab the gaff of the climber in the face of the pole at a point about 8 inches from the ground. Now that the gaff is firmly embedded, lift the weight of your body on the gaff by straightening the leg. Keep the leg your weight is on straight and away from the pole. Although this is a simple habit to develop, it is a fundamental climbing rule. In this way the gaff holds your weight while you grasp the pole with both hands to keep your balance. Now you can raise the other leg and the opposite arm and drive the climber downward to seat the second gaff firmly, as shown in figure 34. Then you are ready to take the next step upward by pulling up and out on the first gaff and moving your foot upward. Reseat the gaff with the same motions used in taking the first step. Be sure to move your hands upward with each step; otherwise your feet may begin to climb past your hands.

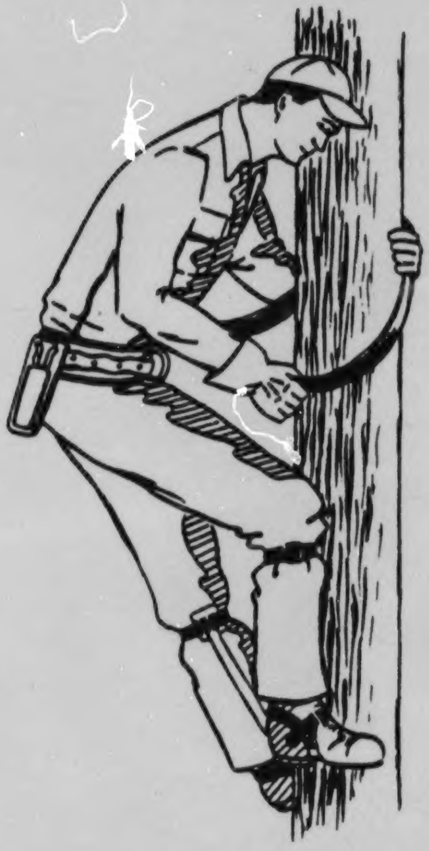


Figure 36. Transferring safety strap.

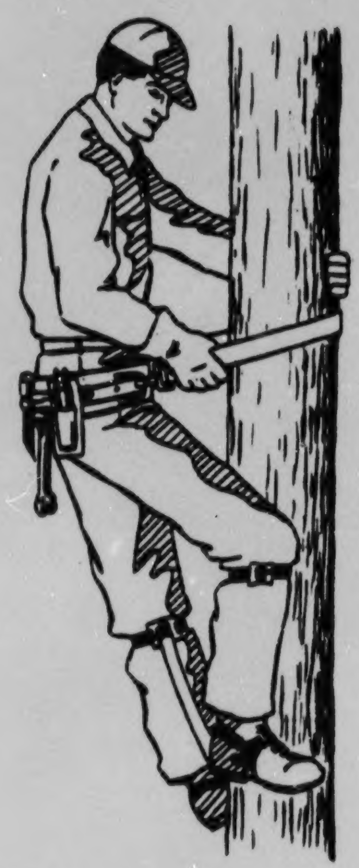


Figure 37. Snapping hook on D-ring.

5-14. All other steps in climbing are merely a repetition of the first steps that you take on the pole. This sequence of motion is followed until you reach the desired height. One thing to re-

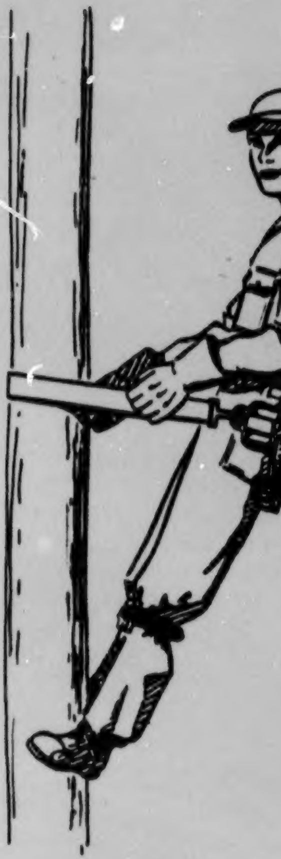


Figure 38. Testing body belt.

member while climbing is to always look upward. Your feet will take care of themselves, as long as your head doesn't butt into a crossarm.

5-15. When descending a pole, reverse the ascending motions. First, break one gaff free of the pole, using the same upward and outward motion that you used in breaking it for climbing. Then flex the other knee and allow your free foot to move down the pole for the distance of a convenient step. Remember, always look down when descending because you must see where your feet are going. If your gaff hits a knot or other obstruction, you may lose your balance.

5-16. After you have learned to climb up and down the pole, you are ready to work on it. If you are to stay in one position and have your hands free for the job, you must know how to fasten the safety strap. At the desired height, shift your weight to one foot. (If you are a right-handed person, put your weight on your left foot.) Then thrust the right gaff into the pole at a slightly higher level than the left gaff. Now place your right hand around the pole, as in figure 35. With the thumb of your left hand, open the keeper of the snap hook and shift the freed end of the safety belt strap around the pole to your right hand. Now, following the example of the lineman in figure 36, transfer the snap hook and equipment to your other hand while balancing your body with your left hand. With your left hand, hold the strap up loosely around the pole; with your right, pull the strap to the right-hand D-ring and snap the hook into the D-ring. CAUTION: Remember to *see* that the snap hook is properly fastened. After all, the keeper can snap without catching the hook, so see that the snap hook is secure, as shown in figure 37. Now put your right hand back on the pole and move the right gaff to approximately the same level as the left gaff. Then you can lean back and carefully place the full weight of your body on the body belt and safety strap. Keep your hands firmly gripped about the safety strap until the snaps, hooks, and belt have been completely tested. Figure 38 shows the lineman while he is testing the body belt. Notice his knees. They are straight and under little muscular strain, because the leg bones are supporting the weight. With the knee joints in this position, he can work with little leg fatigue.

5-17. The safety strap is unfastened in reverse sequence. That is, first move the right gaff up and thrust it in at a slightly higher level than the left gaff. Second, hold the pole with the left hand and unfasten the snap hook from the D-ring with the right hand. Now you can pass the strap around the pole to the left hand while balancing the body with the right hand. Lastly, snap the hook to the left-hand D-ring with a single downward movement. As you become experienced in climbing poles, these fundamental procedures and sequences will become routine.

5-18. This concludes our discussion of the general principles involved in planning a substation installation. Test your understanding of these principles by answering the review exercises in the workbook before proceeding to Chapter 2 where we shall examine the terminal-to-telephone requirements for an installation.

CHAPTER 2

Terminal to Telephone Wiring

THE INSTALLATION of terminal to telephone wiring completes a large part of the job of installing a telephone. As a matter of fact, when the wiring is completed from the terminal pole to the telephone location, the job of finishing the installation is mostly that of connecting and testing the telephone.

2. The wiring system from the terminal to the telephone includes the following:

- The drop wire attachments on the pole and building.
- The drop wire run from the pole to the first building attachment.
- The building run from the first to the last building attachments.
- The protector and ground system.
- The building entrance and inside wiring.
- The connecting block and telephone cord.

3. It is the purpose of this chapter to discuss the components of the terminal to telephone wiring system. However, since termination of the drop wire at the terminal pole is explained in a later chapter, it will not be covered here.

6. Drop Wire Installation Requirements

6-1. That portion of the drop wire between the terminal pole and the first building attachment is called the span run. The general requirements for clearance, appearance, and future development will apply here as well as to other portions of the drop wire run. When installing the drop, you should economize by using the old attachments (either brackets or knobs) which you find on the pole—if they are suitably located. Of course, the drop installation requires a secure fastening at each end of the wire; therefore, select the correct hardware and use proper installation methods. The following paragraphs define and explain the use of pertinent hardware items.

6-2. **Materials for Outside Jobs.** To consider the attachments for outside installation, let us start at the pole end of the span run. With most aerial cable installations, the telephone cable is supported by a suspension strand which extends from pole to pole. This strand is shown in figure 39 with the cable omitted. In an actual installation, the cable is lashed to the lower side of the strand. In figure 39, the use of span clamps is illustrated. As you can see in this illustration, the span clamps are attached to the top of the strand to support the drop wire leading to the stations. This is the same type of installation as shown in figure 6, where the span clamp was used in avoiding a tree. For a closeup view of some typical span clamps, refer to figure 40. The uppermost (A) clamp is made from solid metal with a groove for the suspension strand in each half of the clamp. The lower one (B) is made from heavy sheet metal which is stamped and bent into shape.

6-3. To attach the drop wire to the drive hooks and span clamps as shown in figure 39, devices called drop wire clamps are used. To give you a better view of this item, a typical drop wire clamp is shown in figure 41. This device consists of a loop, wedge, and sleeve which grips the drop wire to support the span. Not only is the drop wire clamp used at the pole-end of the span, but it is also used on the building to fasten the drop wire to the attachments. By using drop wire clamps to support the span run, slack can be maintained in the drop wire at all points of attachment. This minimizes the strain placed on the drop wire by such attachments as drive hooks, drive rings, building attachments, etc.

6-4. Although the wire span is normally fastened to the attachments by drop wire clamps, the means of attaching to the pole or the building depends upon the particular job. For example, the drop wire run may be made from a pole which has a guardarm or from a pole that does not have one. Also, if the drop wire is run made from an open wire line, it is secured to a crossarm. Hardware used to anchor the drop wire or drop wire clamp is considered separately for each end of the drop. Both the drive hook, which must

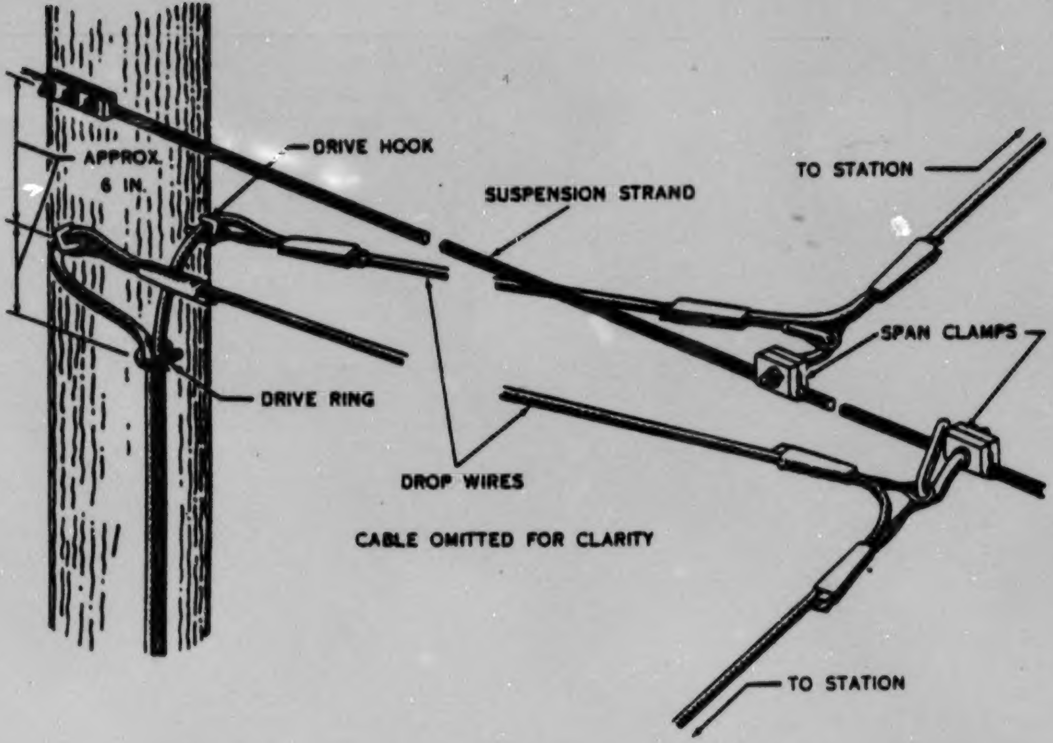

APPROX. 6 IN.
DRIVE HOOK
SUSPENSION STRAND
TO STATION
SPAN CLAMPS
DRIVE RING
DROP WIRES
CABLE OMITTED FOR CLARITY
TO STATION

Figure 39. Pole to span-clamp run.

be hammered into the pole (fig. 42), and the guardarm hook, bolted through the guardarm (fig. 43), are suitable for the pole end of the drop. The attachment on the building, where the work begins, is determined by the structure.

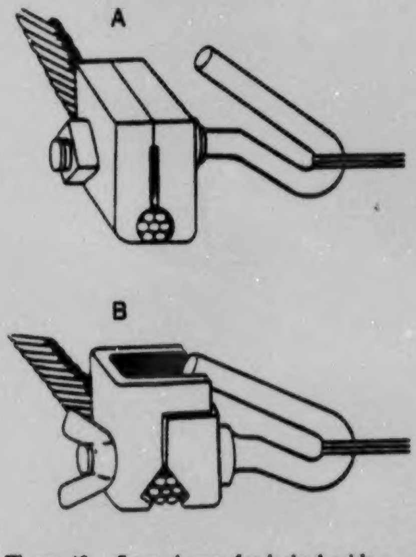


Figure 40. Span clamps for lashed cable.

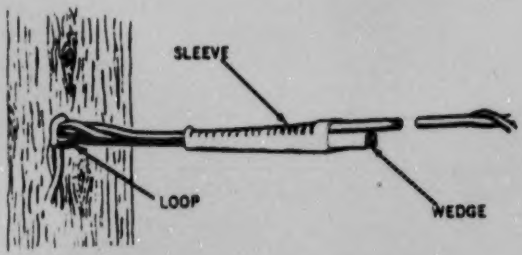

SLEEVE
LOOP
WEDGE

Figure 41. Drop wire clamp installed.

6-5. **Drop Wire Run Requirements.** To install a span run safely, you should observe the following precautions for placing drop wire:

(1) Start at the building end of a drop wire span and work toward the pole; thus, all work can

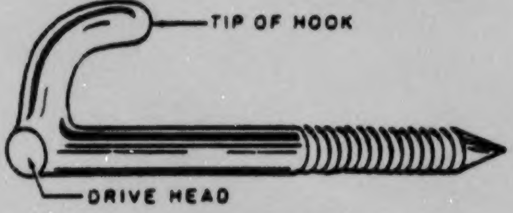

TIP OF HOOK
DRIVE HEAD

Figure 42. Drive hook.

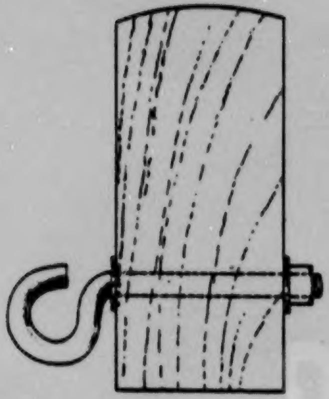


Figure 43. Guardarm hook installed (end view of guardarm).

be done on the building run without blocking any of the ground area under the proposed span. In addition, pulling up and sagging drop wire from a pole or strand position is a safer method for the airman assigned to this job.

(2) Position the ladder against the side of the cable suspension strand away from the drop wire span so that the strand is between the span and any airman working on the ladder.

(3) Do not place the foot of a ladder in a roadway without making adequate provision to guard the ladder from passing vehicles.

(4) Do not perform any construction activities from a ladder placed against the suspension strand until after the ladder has been securely tied to the strand.

(5) When performing any work operations from a ladder place against the strand, attach the safety belt to the strand. Do not pass the safety belt between the rungs of the ladder.

(6) Do not hold a handline or wire in your hand while climbing a pole or ladder; carry it under the body belt. Double the end of the handline back on itself for approximately 1 foot to form a loop, and place this loop under the side or back of the body belt. After getting in position on the pole or ladder, use the handline to hoist any drop or block wire.

(7) Keep wire away from sharp-edged tools in vehicles.

(8) When uncoiling wire without a drop wire reel assembly, reverse the coil every five or six turns to minimize the number of kinks in the wire.

(9) Do not place drop wire where it will cross above power wires unless specifically ordered to do so.

(10) Be very careful to avoid harmful interference with wire raising or lowering operations across roadways. Obtain assistance to control traffic whenever necessary.

(11) When placing more than one drop wire in the building run (this is called a block wire run), make sure that the attachments selected will support the additional weight.

6-6. **Drop Attachment at the Building.** As we said before, the method used to secure drop wire to the building is determined by the building construction and the grounding of the telephone cable involved. If the cable is grounded, noninsulated building attachments, such as metal hooks and bridle rings may be used. However, if the cable is not grounded, attachments to buildings of frame or stucco construction must be of the insulated variety to reduce the possibility of fire caused by lightning or other high voltage surges. Both the noninsulated and insulated attachments are of the screw type, which are anchored by turning the threaded shank or accompanying screw into the wood.

6-7. In your planning for a building run, observe the same rules that apply to the span portion of the drop wire run. For example, locate the first attachment so that the drop will have the necessary clearance above roadways and footways, will clear electric light and power wires, and will be separated from inflammable or conducting materials.

6-8. If the installation consists of one drop attached to a masonry or brick veneer structure, you may use one drop wire clamp to carry the weight of the pole-to-building span and another drop wire clamp to support the building run, as shown in A of figure 44, or you may use an S-wire clip on the building run. (See B and C of fig. 44.) Note that the S-wire clip may also be used for frame buildings, as illustrated in B of figure 44. When you attach a second drop to a drop wire hook, remove the drop wire clamp from the building run of the first drop and place a C-knob (split knob) about 6 inches behind the first span attachment. Figure 45 shows this arrangement.

6-9. The hardware for building attachments is selected and installed on the various surface types by following standard practices. Usually, you have only one best choice for any situation you face. Figures 46 and 47 show S-knobs and T-knobs with brackets. Figure 48 shows these same knobs with angle screws, and figure 49 shows them with insulator supports. When these brackets, insulator supports, or screws are used on frame buildings, they require the knobs shown. The drop wire hooks may be used on frame buildings, as shown in figure 50, when the telephone cable is properly grounded. An S-knob

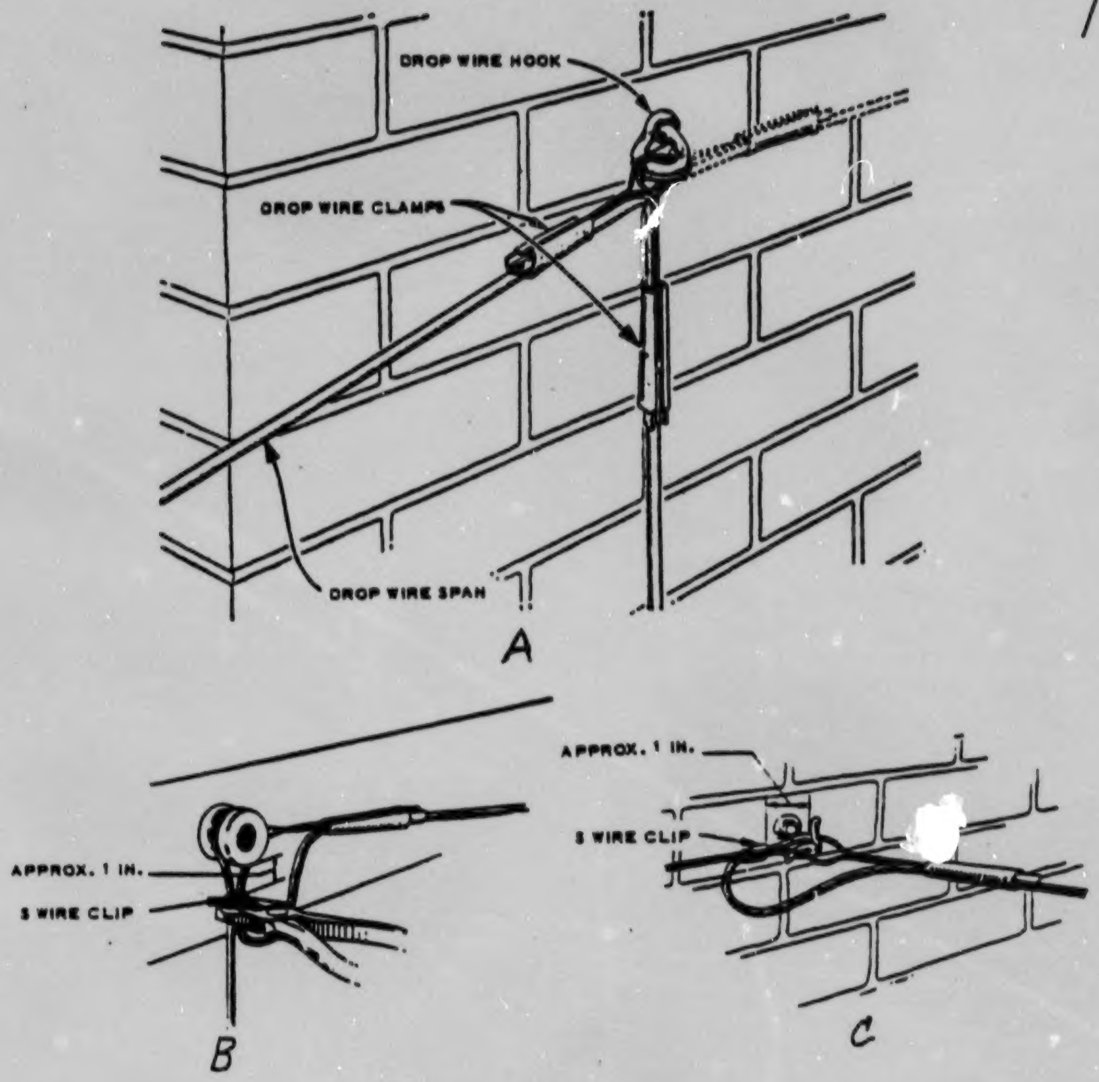

DROP WIRE HOOK
DROP WIRE CLAMPS
DROP WIRE SPAN
A
APPROX. 1 IN.
S WIRE CLIP
B
APPROX. 1 IN.
S WIRE CLIP
C

Figure 44. Drop wire clamps installed.

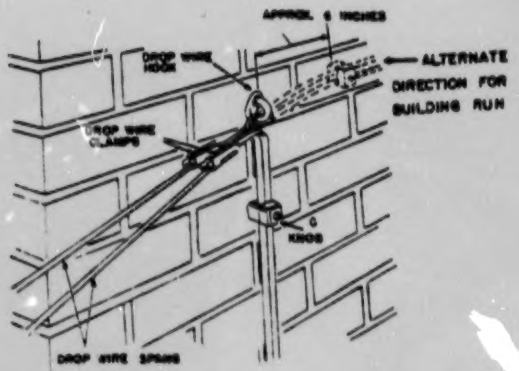

APPROX. 6 INCHES
DROP WIRE HOOK
ALTERNATE DIRECTION FOR BUILDING RUN
DROP WIRE CLAMPS
G KNOB
DROP WIRE SPANS

Figure 45. Two drop wire spans attached to building.

is used when only a single drop wire is involved. Two drop wires require a T-knob.

6-10. On masonry construction the brackets, hooks, and attachments must be provided with anchors of some sort. Part A of figure 51 shows two types of hammer drive anchors with a nail providing the wedging element. In B of figure 51, we see the anchor inserted through the mounting hole of the fixture and into the drilled hole in the masonry wall. Driving the nail into the anchor expands the sides, making the anchor fit tightly in the hole. The screw anchor, shown in figure 52, operates on the same principle. After inserting the anchor into the drilled hole, the wood [illegible] is placed through the mounting hole of the

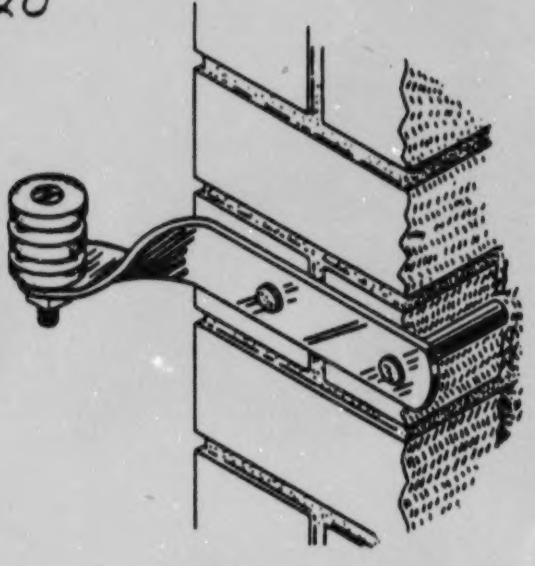


Figure 46. Corner bracket.

fixture and into the anchor. Tightening down on the screw causes the anchor to expand and hold. A bridle ring with a wood screw thread may be used with this type of anchor. Toggle bolts, similar to those shown in figure 53, are used on hollow tile or concrete block walls. The hole must be large enough to take the toggle, as shown in the illustration. When angle screws, wire hooks, and bridle rings are used on frame installations, they should be arranged so that the wire pull will tend to turn the screw deeper into the wall.

6-11. Between the first and the last building attachments, the drop wire run on the building must be held in place and guided by rings or screw eyes. These supporting devices are referred to as intermediate attachments. Figure 54 shows a bridle ring (A) and corner bridle rings (B) installed on brick surfaces; figure 55 shows

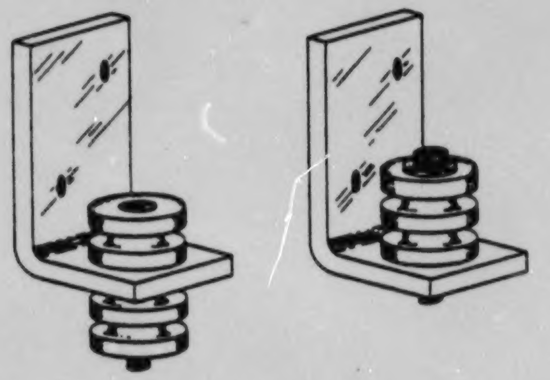


Figure 47. House brackets.

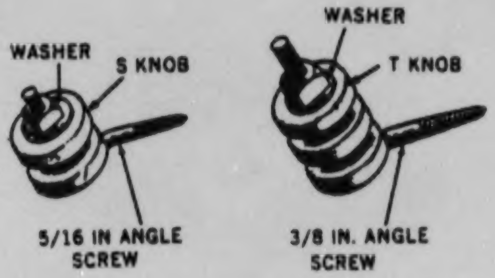


Figure 48. Angle screws.

insulated screw eyes installed on surfaces of wood and stucco on wood. The short shank (S-type) is sufficient for wood surfaces. A longer shank (L-type) is required when the outer surface is stucco.

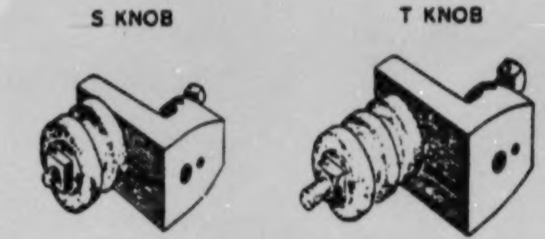


Figure 49. Universal insulator supports.

6-12. The use of intermediate attachments on buildings is determined by the requirements for keeping the distance between the attachments on horizontal runs within a maximum range of 9

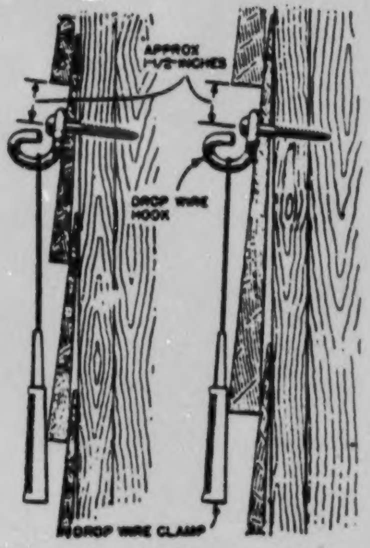


Figure 50. Drop wire hook installations (clapboards and shingles in unexposed area).

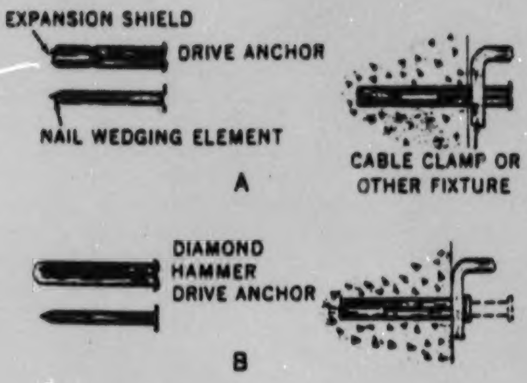

EXPANSION SHIELD
DRIVE ANCHOR
NAIL WEDGING ELEMENT
A
CABLE CLAMP OR
OTHER FIXTURE
DIAMOND
HAMMER
DRIVE ANCHOR
B

Figure 51. Drive anchors.

feet. The distance between attachments on vertical runs must be kept within a maximum length of 12 feet. Intermediate attachments are placed so that they will divide as evenly as possible the distance between the first and the turn attachments on a horizontal run and the distance between the turn and last attachments on a vertical run. If the vertical run begins with the first attachment, the distance between the first and last attachments is divided. Such placings give the drop more security and a better appearance. When you use additional attachments, allowances must sometimes be made to keep exposed wires clear of frame buildings or to prevent wires from slapping the building.

6-13. Mechanical protection must be provided whenever necessary on the building run by installing friction tape, rubber and friction tape, or an insulating tube on the wires of the building run at the points requiring protection. The use of friction tape alone is restricted to noninsulated runs at obstructions other than open electric, radio, ground, or signal wires. Both rubber tape and friction tape or an insulating tube must be

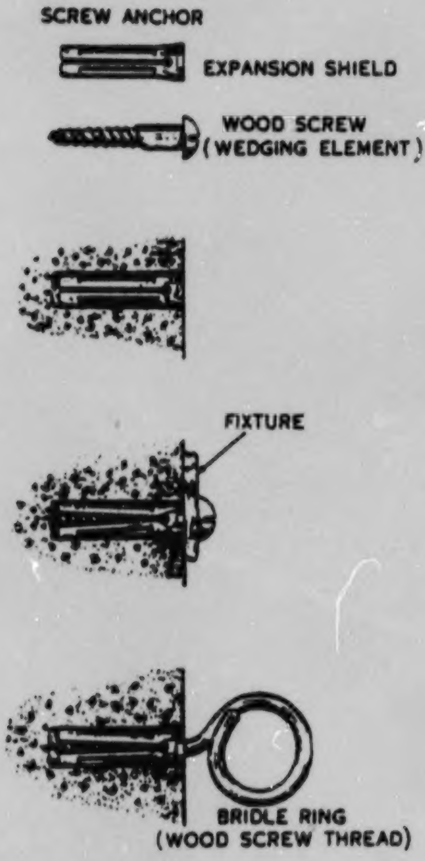

SCREW ANCHOR
EXPANSION SHIELD
WOOD SCREW
(WEDGING ELEMENT)
FIXTURE
BRIDLE RING
(WOOD SCREW THREAD)

Figure 52. Screw anchors.

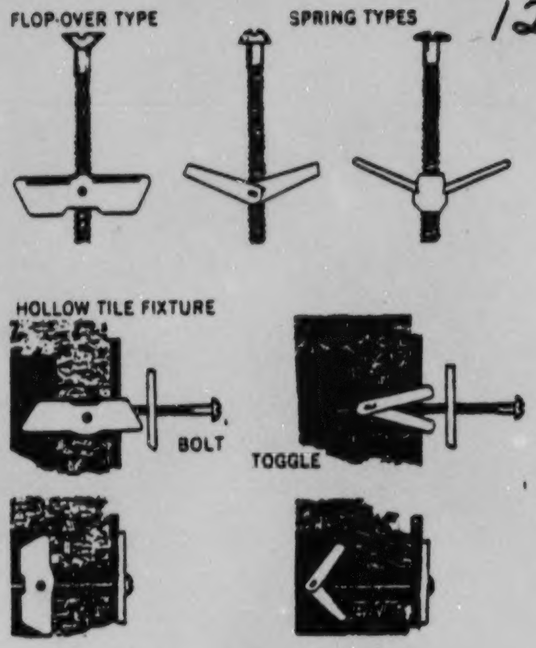

FLOP-OVER TYPE
SPRING TYPES
HOLLOW TILE FIXTURE
BOLT
TOGGLE

Figure 53. Toggle bolt anchors.

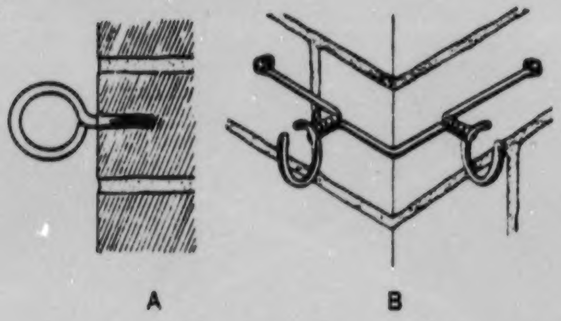


Figure 54. Bridle ring installation.

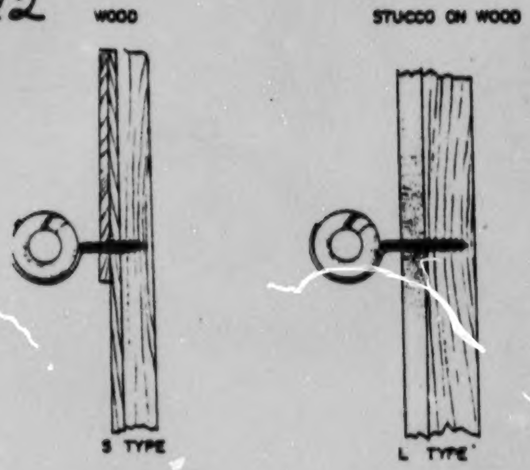


Figure 55. Use of short and long insulated screw eyes.

used when mechanical protection is required on insulated building runs.

6-14. Insulating tubes are of two types: solid and split. The solid tube is intended for new building run installation and, whenever practical, for existing installations that require such protection. The split tube is intended only for existing building runs when installing a solid tube is not practical. Using the split tube makes it unnecessary to disconnect or cut an existing wire in order to thread it through a solid tube. Tubes may be obtained in three sizes: ⅜-, ¾-, and 1-inch diameter.

6-15. Always select an insulating tube with a large enough diameter to accommodate the ultimate number of wires that will be placed in the building run. Except at entrance holes, use a tube that is long enough to extend at least 2 inches beyond each side of the object to be crossed by the drop or block wires. After tubes are cut to the correct length, remove all sharp edges at the cut end with a carborundum stick.

6-16. Install a solid insulating tube by passing the end of the drop wire through the tube and sliding the tube along the wire to the desired location. Install a split insulating tube by securing the two halves of the tube around the drop wire with lashing wire about 1 inch from each end of the tube to keep the tube halves together. Twist the ends of each lashing wire together and bend the twisted ends back against the tube so that they will not catch on clothing or hurt anyone.

6-17. After you have positioned an insulating tube, secure it in place on the drop wire with a drop wire clip, drive ring, split knob, or insulated screw eye at each end of the tube, as shown in figures 56 and 57.

6-18. In using rubber tape to protect drop wire, place enough tape around the wire to provide a cover for at least 2 inches past both ends of the obstruction. Then cover this length of the wire with two reversed half-lapped layers (four thicknesses) of ¾-inch rubber tape applied with enough tension to double the tape length. Start at the center of the obstruction and wrap the tape out to 2 inches beyond the end of the obstruction to be crossed. Now reverse wrap to 2 inches beyond the other end of the obstruction. Reverse wrap again and end at the center. Place friction tape over the layers of rubber tape.

6-19. When the drop wire runs behind a rainspout, place the supporting attachments at the ends of the protection. If tape protection is used at a rainspout on masonry surface, you may position the supporting attachments away from the ends of the protection to provide a more convenient position for the attachments, as shown in figure 58. In no case, however, should the supporting attachments be placed more than 12 inches away from the ends of the obstruction.

6-20. When the drop wire runs in front of a rainspout, place the supporting attachments not more than 12 inches from the ends of the obstruction and in such a way that they will hold the protected portion in place against the rainspout without causing any sharp bends in the wire. If an insulating tube is used for protection, secure the tube in place with a drop wire clip placed at each end of the tube (view B–B, fig. 57). If drive rings are used, tie the drop wire to the

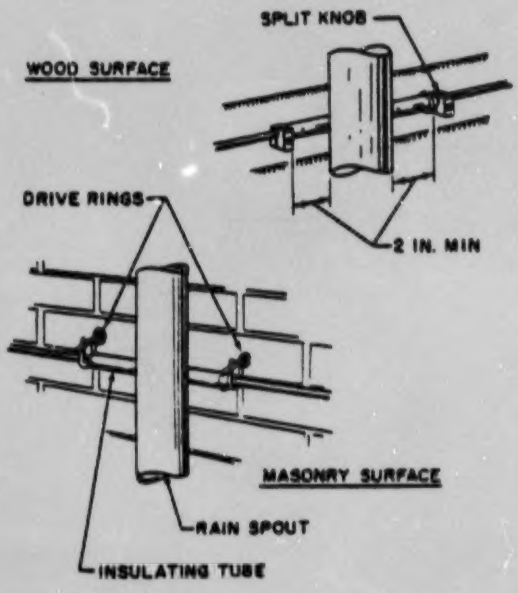


Figure 56. Insulating tube installation.

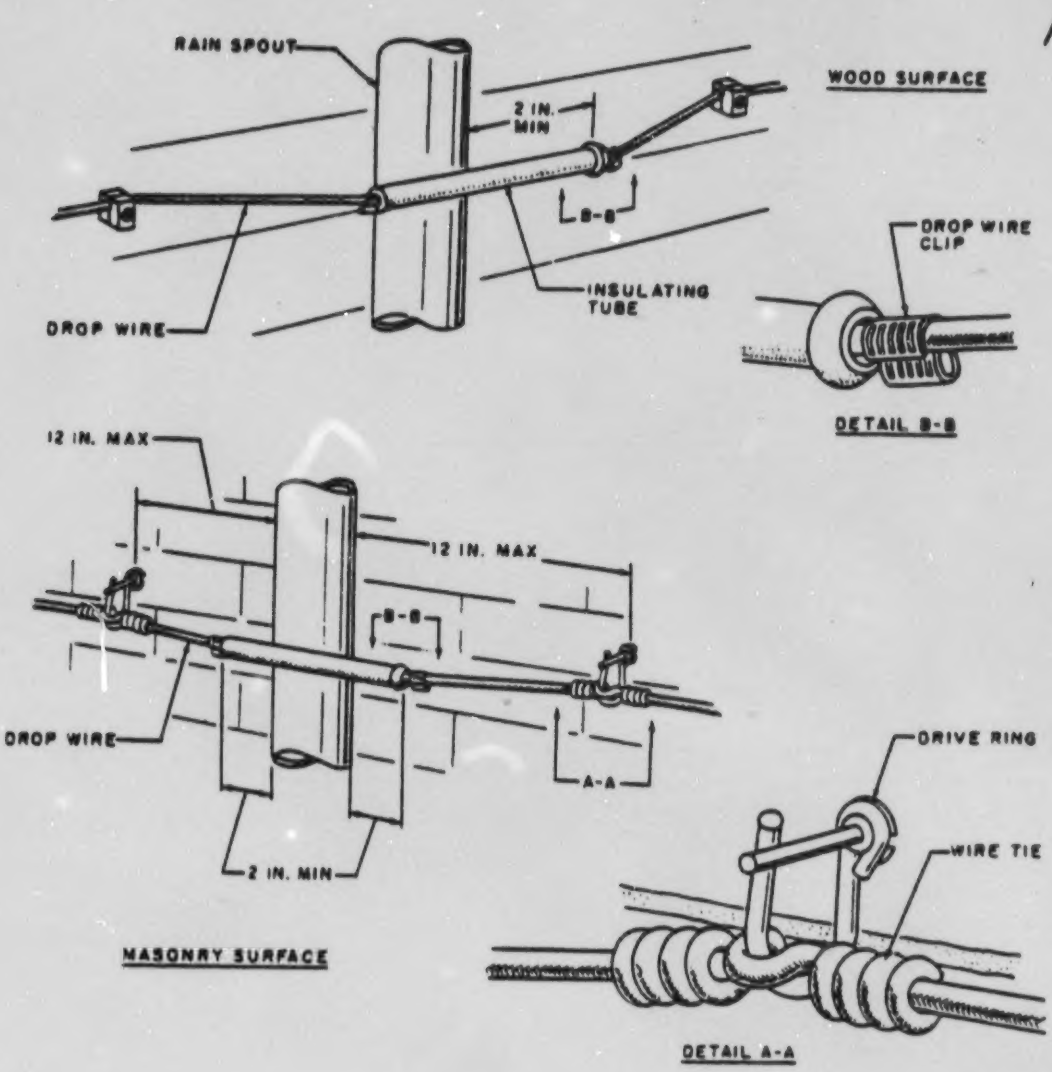

RAIN SPOUT
2 IN. MIN
WOOD SURFACE
B-B
DROP WIRE CLIP
INSULATING TUBE
DROP WIRE
DETAIL B-B
12 IN. MAX
12 IN. MAX
B-B
DROP WIRE
A-A
DRIVE RING
WIRE TIE
2 IN. MIN
MASONRY SURFACE
DETAIL A-A

Figure 57. Insulating tube attachment.

drive rings (view A–A, fig. 57), using a short length of bridle wire for each tie.

6-21. The drop wire run on the building frequently must turn corners. Figure 59 shows the attachments used for guiding the drop wire around an outside corner. In A of figure 59, we see a corner type bridle ring arrangement, while B shows two screw type bridle rings used to guide the drop wire around the corner. Figure 59,C, illustrates two porcelain C-knobs used on wood to turn a corner. An inside corner is made in a similar manner by using screw type bridle rings or insulated screw eyes. Figure 60 shows how to turn corners when the drop wire run changes from a horizontal to a vertical direction. Note that figure 60 shows both single and multiple wire installations. If necessary, drop wire hooks can be used in place of bridle rings.

6-22. The last attachment of the drop wire run on the building is the one just before entrance into the building. Figure 61 shows a typical entrance and last attachment. Note that the drop wire is installed with a drip loop to prevent moisture from following the wire into the building.

6-23. As we mentioned previously, frame structures require knobs and insulated screw eyes for drop wire attachments when the cable sheath is not grounded. Figure 62 shows a typical frame building run in which the first attachment is made with a C-knob, and the run includes a horizontal section, a turn made with insulated screw eyes.

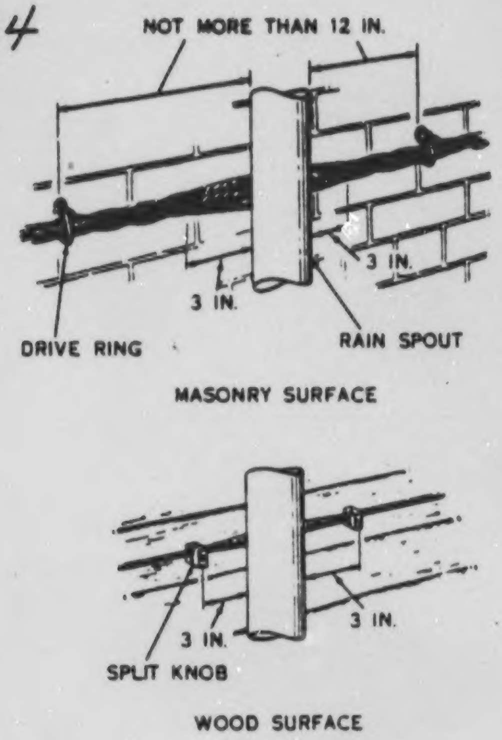

NOT MORE THAN 12 IN.
3 IN.
3 IN.
DRIVE RING
RAIN SPOUT
MASONRY SURFACE
3 IN.
3 IN.
SPLIT KNOB
WOOD SURFACE

Figure 58. Use of protective tape.

and a vertical section. Note that the horizontal section, which runs parallel with the building siding from the first attachment to a point above the entrance, avoids windows or other obstructions. Note also that the vertical run does not pass in front of windows and that it is truly vertical as it goes to the C-knob, which is the last attachment.

6-24. Remember that insulated screw eyes should be placed at least 5 feet above the ground line in alleyways or other locations close to a street so that the porcelain portion of the screw eye will not be damaged by people using the thoroughfare. If lower attachments must be made, use split (C) knobs instead of the insulated screw eyes.

6-25. Drop wire runs on brick buildings are installed by applying the same principles as those used for installations on frame buildings. In figure 63 you see that the drop wire run on the brick is attached by drop wire hooks or bridle rings and that the entrance is made near a window. You should place the run along a smooth part of the brick rather than along rough foundations. Be sure that the run avoids obstructions and that the attachments are anchored in the center of the brick rather than in the mortar between bricks.

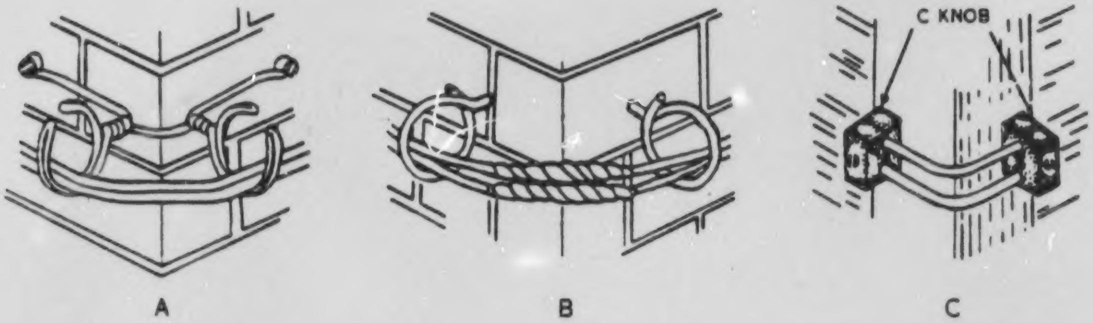


Figure 59. Outside corner attachments.

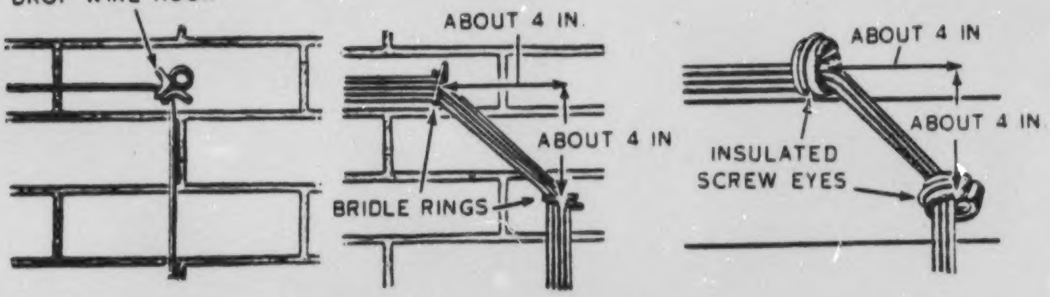

DROP WIRE HOOK
ABOUT 4 IN.
ABOUT 4 IN
BRIDLE RINGS
ABOUT 4 IN
ABOUT 4 IN
INSULATED
SCREW EYES

Figure 60. Turn attachments.

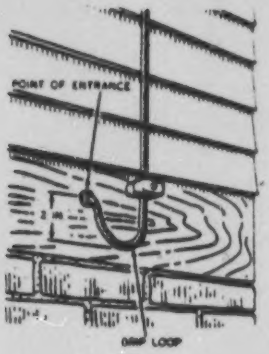

POINT OF ENTRANCE
2 IN.
DRIP LOOP

Figure 61. Last attachment with drip loop.

6-26. Stucco construction, as shown by figure 64, requires attachments to suit the basic construction of the building. Since the building shown in figure 64 is stucco over frame, the attachments shown are those which would be used for a frame building. If the stucco is over a masonry building, masonry type attachments should be used.

6-27. **Drop Attachment at the Pole.** As we mentioned before, drive and guardarm hooks are used as attachments on the terminal pole. Let us now consider how these attachments are used. Both the guardarm hook and the drive hook are installed according to standard practices. That is, drive hooks should be staggered at least 1 inch when two are installed on the same pole (fig. 65) and should be placed to give the drop wire proper appearance and clearance. The vertical distance from the suspension strand to the drive hook may be varied to obtain proper clearance. Figure 66 shows two drops from the same terminal pole. Note the location of the drive hooks and also note that one drop wire is resting on the shank of the drive hook. This is permissible when the angle between the drop and the pole is such that a sharp bend is avoided. From the drive hook, the drop wire runs through drive or bridle rings to the terminal. When a vertical run is on the pole, pull the ring wiring taut to eliminate unsightly slack; however, don't pull the wire so taut that the strain is taken off the drop wire clamp and placed on the drop wire itself.

6-28. Drive hooks are not used when the pole requires a guardarm; instead, the drop wire is attached to guardarm hooks on the guardarm, as shown in figure 67. The guardarm hooks provide a solid fastening on the guardarm, just as the drive hook did on the pole, and the installation is completed in essentially the same manner. The necessity for avoiding slack and for obtaining the proper clearance applies here also.

6-29. When the drop is attached to an open wire line, the guardarm hook is used on the crossarm in making the installation. When this method is used, make sure that the hook is installed in a position so that the drop wire span

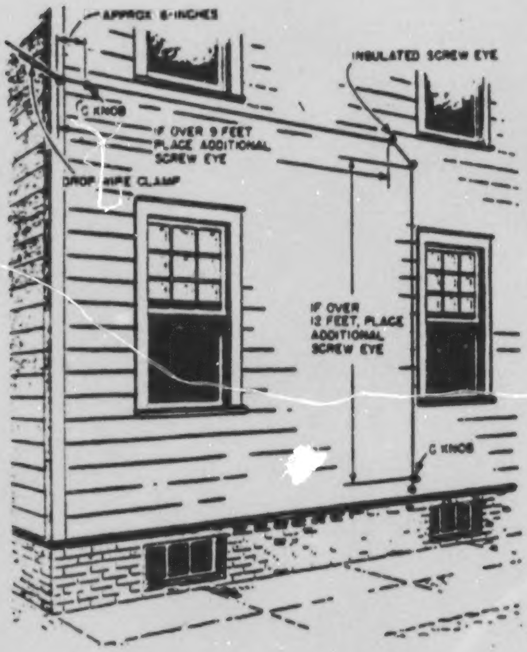

APPROX 6-INCHES
INSULATED SCREW EYE
C KNOB
IF OVER 9 FEET PLACE ADDITIONAL SCREW EYE
DROP WIRE CLAMP
IF OVER 12 FEET, PLACE ADDITIONAL SCREW EYE
C KNOB

Figure 62. Drop wire run on frame building.

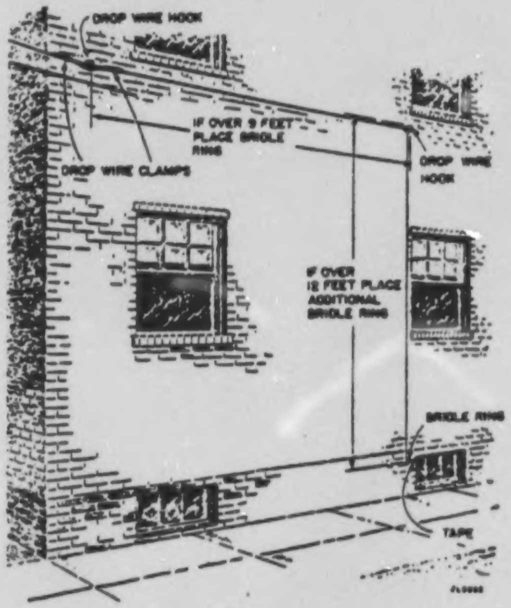
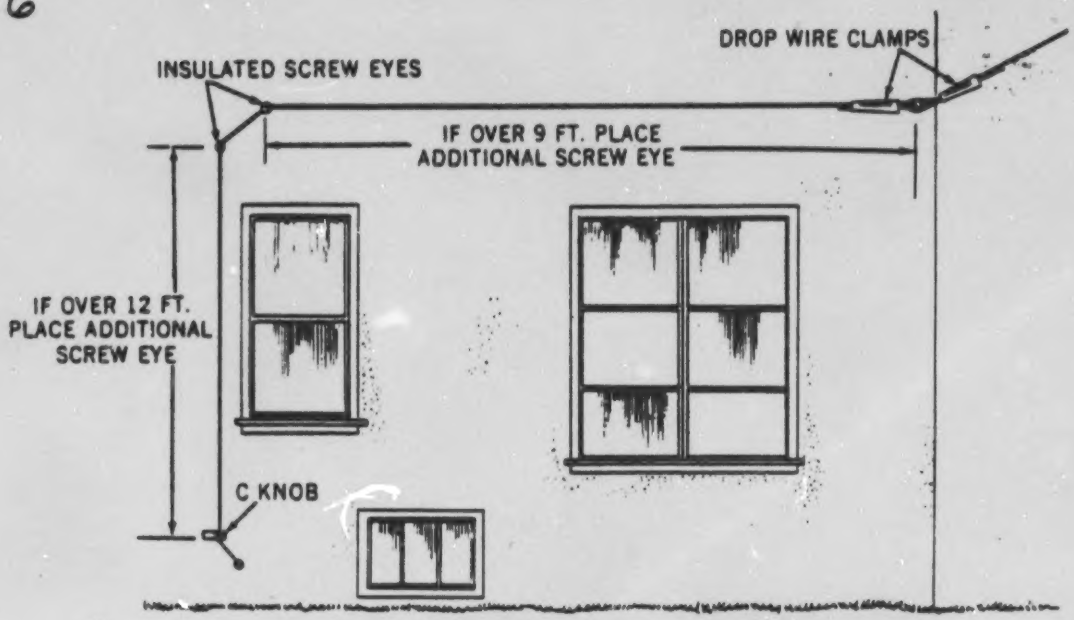

DROP WIRE HOOK
IF OVER 9 FEET PLACE BRIDLE RING
DROP WIRE CLAMPS
DROP WIRE HOOK
IF OVER 12 FEET PLACE ADDITIONAL BRIDLE RING
BRIDLE RING
TAPE

Figure 63. Drop wire run on masonry building.


DROP WIRE CLAMPS
INSULATED SCREW EYES
IF OVER 9 FT. PLACE ADDITIONAL SCREW EYE
IF OVER 12 FT. PLACE ADDITIONAL SCREW EYE
C KNOB

AT INSTALLATIONS WHERE STUCCO-FINISH WALLS HAVE NO WOOD BACKING, TURN MAY BE MADE WITH ONE INSULATED SCREW EYE PLACED IN STUDDING.

Figure 64. Drop wire run on stucco-over-frame building.

will clear the open wire lines. Open wire termination will be discussed further in Chapter 3.

7. Underground Distribution Wiring

7-1. At some time or other you may be required to make an underground installation between the terminal pole and the subset. This type of installation usually requires the use of underground distribution wire and, of course, different methods of installation.

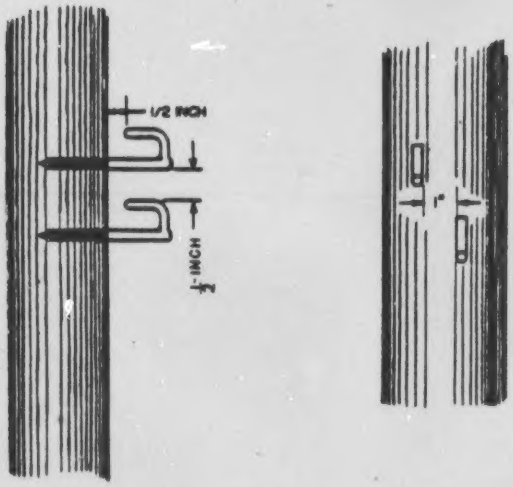

1/2 INCH
1/2 INCH
1"

Figure 65. Drive hooks installed on pole.

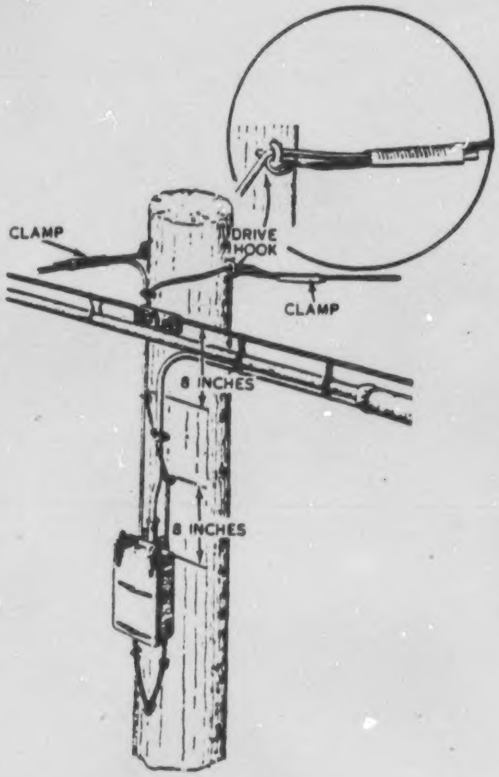

CLAMP
DRIVE HOOK
CLAMP
8 INCHES
8 INCHES

Figure 66. Location of drive hooks on terminal pole.

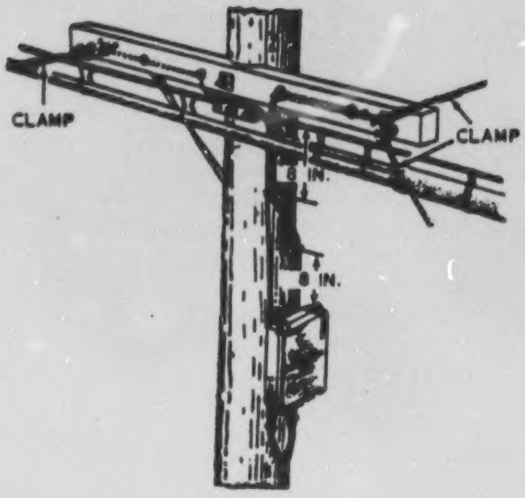

CLAMP
CLAMP
8 IN.
8 IN.

Figure 67. Location of guardarm hooks at terminal pole.

7-2. **Underground Wire.** Figure 68 shows a typical single-pair, parallel-jacketed, underground distribution wire, which is available in one- and two-pair sizes. Note that the rubber insulated conductors are protected by a steel serving and a weatherproof neoprene jacket. A tracer ridge or groove is provided on the insulation of one wire of each pair. When it is necessary to make an underground installation, the appropriate wire must be selected for the job, as specified in technical orders on drop wire and station installation.

7-3. **Installation.** The wire or cable for underground service installations may be buried directly in the ground or run through conduit. The usual practice is to bury the wire or cable, unless conduit facilities already exist. But you may

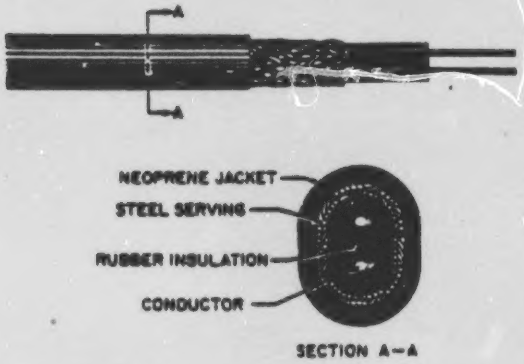

A
A
NEOPRENE JACKET
STEEL SERVING
RUBBER INSULATION
CONDUCTOR
SECTION A—A

Figure 68. Pair arrangement of parallel-jacketed underground distribution wire.

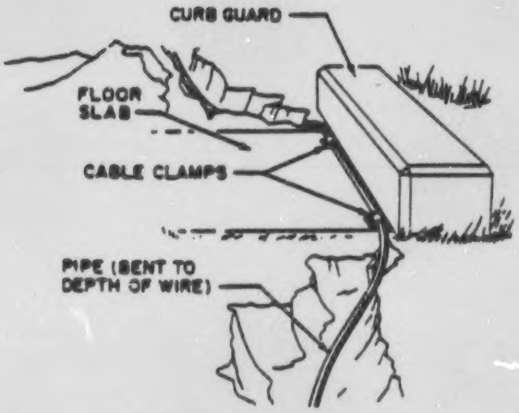

CURB GUARD
FLOOR SLAB
CABLE CLAMPS
PIPE (BENT TO DEPTH OF WIRE)

Figure 69. Pipe position for bridge crossing.

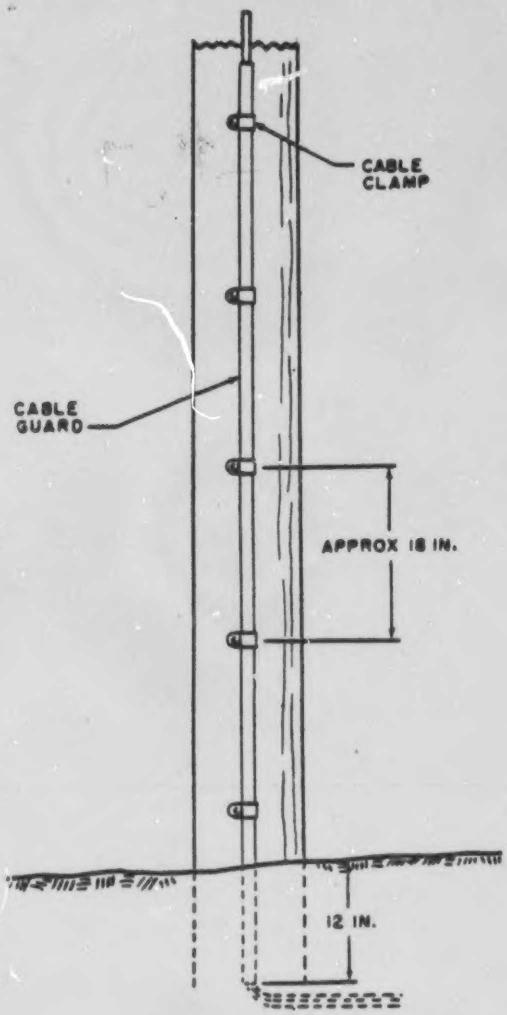

CABLE CLAMP
CABLE GUARD
APPROX 18 IN.
12 IN.

Figure 70. Mechanical protection for underground wire at pole.

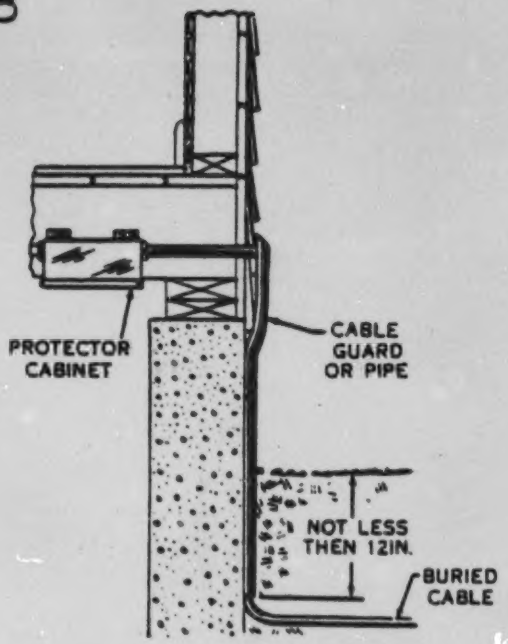


Figure 71. Mechanical protection for underground wire at station.

have to install galvanized-pipe conduit to provide mechanical protection at critical points or locations of directly buried runs, such as runs across drainage ditches, roadways, small bridges, and through culverts.

7-4. If soil conditions permit and a wire plow is available, underground distribution wire or service cable may be plowed under the ground. Otherwise, the wire is buried in a hand- or machine-dug trench, which should not generally be more than 12 inches wide. The width, however, will depend on the conditions of the job location and the digging tools available.

7-5. All personnel engaged in wire-burying operations must observe the following precautions:

(1) Be sure to bury the wire or cable deep enough to prevent damage by heavy vehicles crossing the buried line.

(2) When placing wire along roadways or across ditches, avoid locations that might interfere with natural drainage.

(3) Avoid careless handling of wire and reels while they are in transit and during the placing procedures.

(4) Do not remove lagging from the wire reels until the wire is ready to be placed in the ground. Exposure to light and moisture may cause deterioration of the rubber insulation; therefore, cover exposed reels with a tarpaulin when the weather is wet.

(5) Do not permit vehicles to be driven over wire or cable that is lying on the ground.

(6) If the wire or cable is to be placed in an excavated trench, as it is placed check the wire or cable carefully for cuts, nicks, and breaks. Make any necessary repair or replacement.

(7) Allow a sufficient length of the wire or cable to extend at both ends of the run to permit proper terminations.

7-6. In general, a depth of 18 to 20 inches will provide a good, protective earth covering for buried wire or service cable. The actual depth of placement, however, will depend on the conditions along the wire route and the operating efficiency of the digging and burying tools and equipment.

7-7. If the minimum placement depths listed in pertinent tables cannot be met, additional mechanical protection must be provided or an alternate wire route selected. For example, mechanical protection, such as galvanized pipe, split

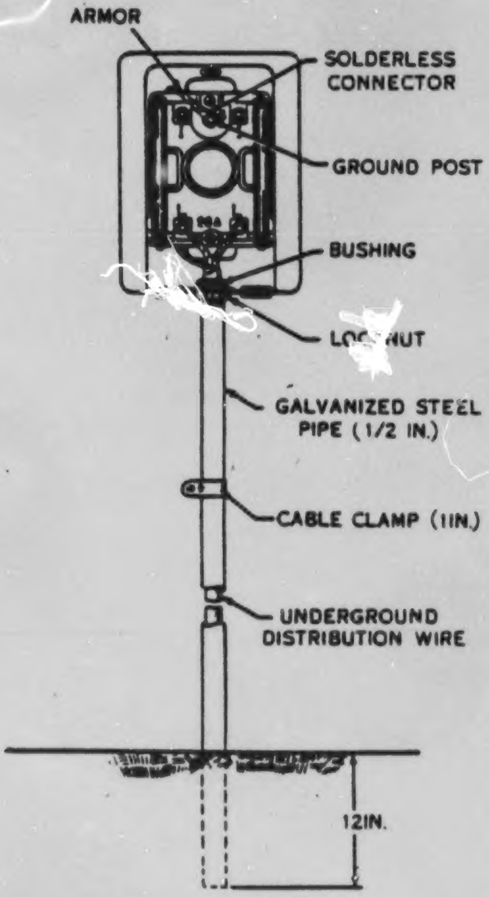


Figure 72. Mechanical protection at outside station protector.

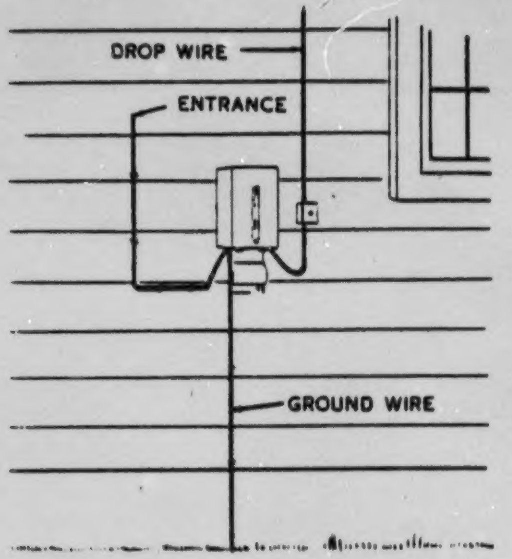


Figure 73. Outside protector mounting.

wood conduit, and U-cable guards, is necessary for underground distribution wire or service cable at locations where the wire or cable is, or is likely to be, exposed to mechanical damage or weathering.

7-8. When buried service wire must cross roadways or streams, galvanized pipe should be used for protection. Figure 69 shows a pipe installation in which the pipe is secured in position so that it will not be dislodged by traffic or cleaning.

7-9. Of course, guard pipe for underground services is also necessary at the ends of the installation. Figure 70 shows protection at a terminal pole at the line end, and figures 71 and 72 show protection at the station end. Note that pipe covering is provided from a point approximately 12 inches below the ground surface to the protector cabinet.

7-10. If you must make an underground installation, follow the procedures as set forth in pertinent technical orders and you should have very little trouble. From this discussion on underground wiring, then, let's shift our attention to the protectors, which ground dangerous potentials.

8. The Entrance Hole and Station Protector

8-1. To extend the telephone wiring into the building, an entrance hole must be provided at some convenient location. The hole should be located to provide the shortest possible outside building run without causing inside wiring problems. Also, some consideration should be given to the location of the protector with respect to the entrance hole location. Since the protector may be located either inside or outside of the building and also requires a good ground, it would simplify the job of installation to locate the entrance hole and protector adjacent to an existing ground (water pipe, gas pipe, etc.). Whenever possible,

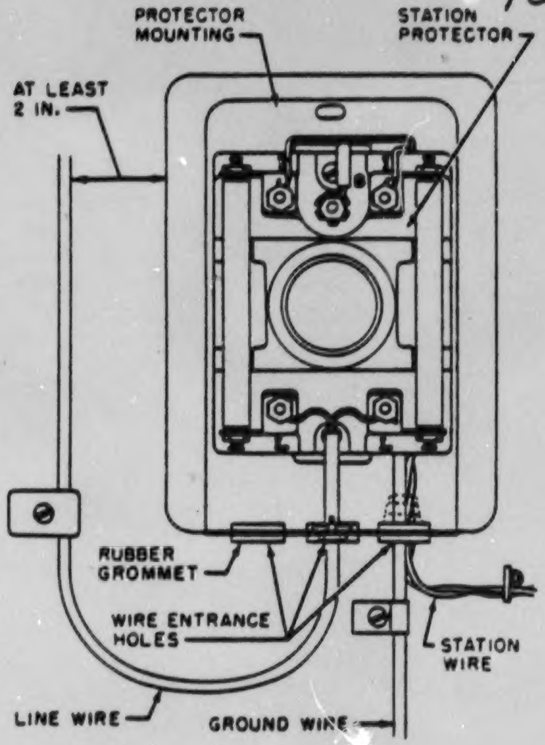


Figure 74. Conductor arrangement in an outside protector.

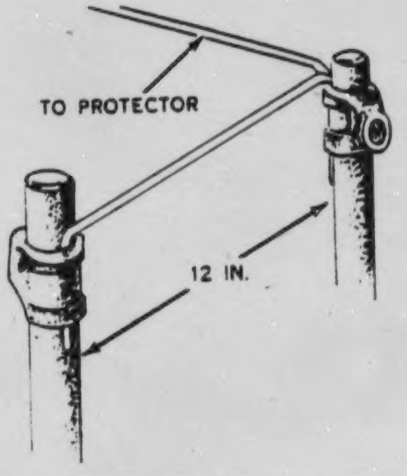


Figure 75. Use of two ground rods.

it is best to select a point for the entrance hole immediately above the building foundation sill or make the entrance at a wooden frame, either a door or a window. Entrance through metal frames should be avoided.

8-2. **Drilling the Hole.** After the location for the entrance hole has been determined, the hole is then made by using a drill. In general, the hole should be made large enough to accommodate the immediate and anticipated number of wires that will go into the building; however, do not make the hole diameter greater than one-half the width of the material through which the hole is made. Rather than make a hole with too large a diameter, drill two small holes. If an insulating tube is used, drill a hole just large enough for the tube to enter. The proper hole sizes for the various insulated tubes are usually given in technical orders on installation.

8-3. To help keep moisture out of the building, entrance holes should be drilled so that they slope upward from the outside. When entering through brick walls, make the hole in a seam between the bricks. It is a good practice to drill from the side where a good appearance is most desirable.

8-4. When it is necessary to locate the entrance hole at metal window frames set in concrete, drill halfway from the inside of the building and halfway from the outside. Start the holes so that they meet approximately 3 inches behind the visible end of the window frame.

8-5. The entrance holes for exposed stations require the use of insulating tubes, except as follows:

- When service entrance conduit is used, no tube is required.
- When the entrance hole is made entirely through brick or masonry, no tube is required.

When making the installation, at least ¼ inch of the tube should project beyond the surface of the wall. However, it should not have more than a 1-inch projection; the tube should be cut if necessary. In addition, the tube must fit snug in the entrance hole. If it does not, place sufficient layers of friction tape around the outside end of the tube to insure a snug fit.

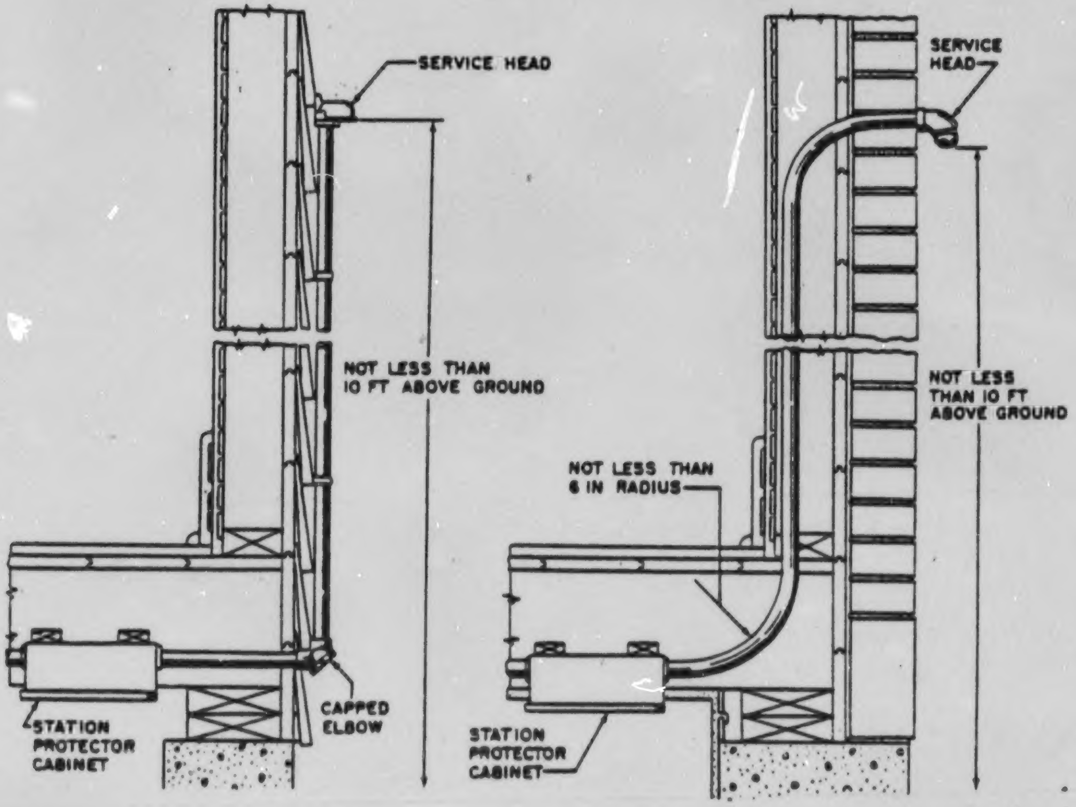

SERVICE HEAD
NOT LESS THAN 10 FT ABOVE GROUND
STATION PROTECTOR CABINET
CAPPED ELBOW
SERVICE HEAD
NOT LESS THAN 10 FT ABOVE GROUND
NOT LESS THAN 6 IN RADIUS
STATION PROTECTOR CABINET

Figure 76. Typical service conduit where protector cabinet is inside building.

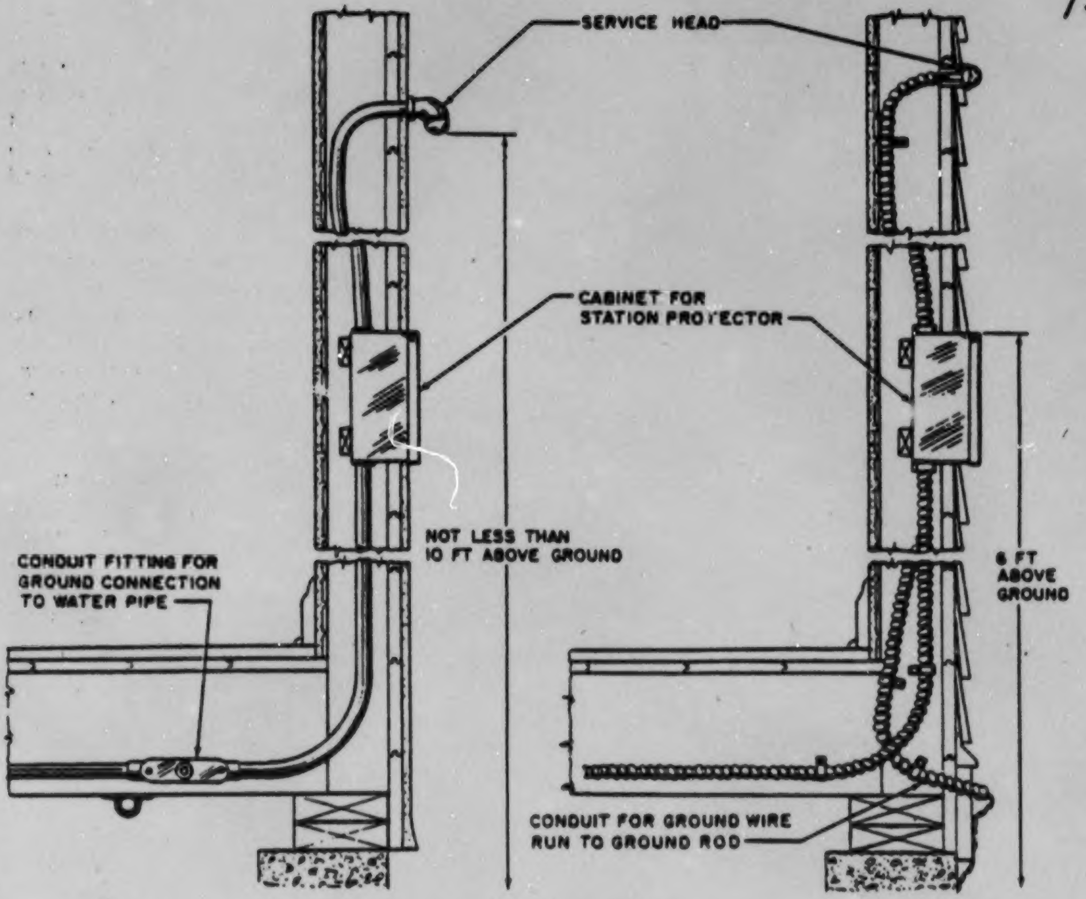

SERVICE HEAD
CABINET FOR STATION PROTECTOR
NOT LESS THAN 10 FT ABOVE GROUND
CONDUIT FITTING FOR GROUND CONNECTION TO WATER PIPE
8 FT ABOVE GROUND
CONDUIT FOR GROUND WIRE RUN TO GROUND ROD

Figure 77. Typical service conduit where protector cabinet is outside building.

8-6. **Protector Installation.** As mentioned previously, the protector safeguards the station from excess voltages and currents. To do this, however, it must be installed correctly and must be in proper working order.

8-7. Protectors are designed for both indoor and outdoor installation. The outdoor protectors, however, must have covers to protect them from the weather. The function of indoor and outdoor protectors is basically the same. That is, when excessive current flows through either fuse, heat is produced, melting the fuse element and opening the circuit. High voltage, however, is grounded by means of a carefully designed airgap. This airgap is quite small—spacings between 3/1000 inch and 25/1000 inch are common. If protectors are improperly mounted, carbon dust can fill this small gap and create a permanent ground. Sometimes a permanent ground is created by the heat from lightning.

8-8. Station protectors should be located where they are readily accessible for inspection

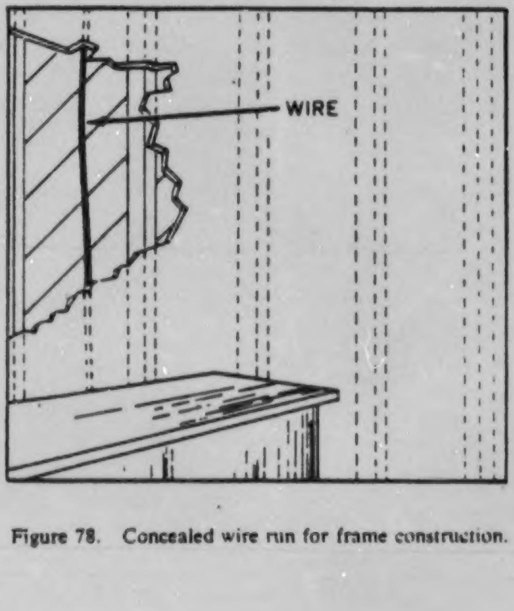


Figure 78. Concealed wire run for frame construction.

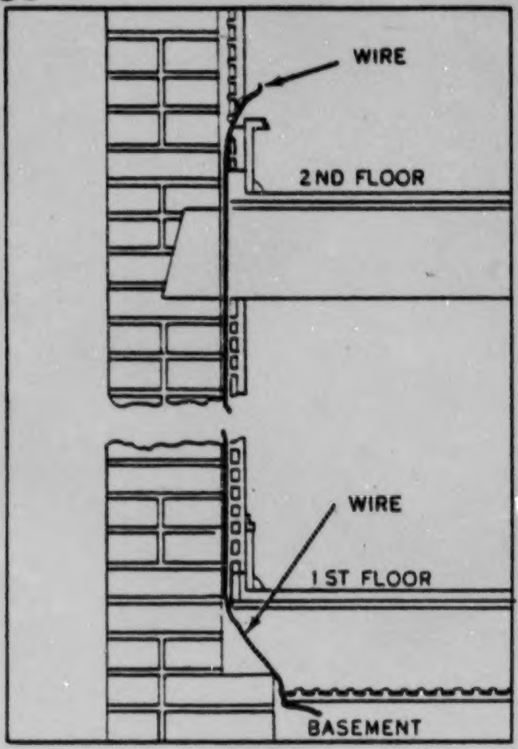


Figure 79. Concealed wire run for masonry construction.

and maintenance and as close as possible to the entrance hole. A location should be selected which permits the use of a short ground wire directly connected to its grounding device. Figure 73 shows a typical outside protector mounting. When a protector is mounted outside, it should be placed no more than 5 feet above the ground level. A clearance of 1 foot or more is required between the protector and any power installation.

8-9. Figure 74 shows a typical conductor arrangement for an outside protector. Note that all wiring leaves the protector at the bottom. Also note that the line wiring connects to the two lower terminals in the protector, and the station wiring connects to the two outside terminals near the top. The ground wire connects to the center terminal at the top. With an inside protector, this situation may be reversed. That is, the ground wire and the station wires may be connected at the bottom of the protector and the line wires connected to the top. This means, of course, that the protector would be installed with its ground and station wire terminals at the bottom rather than at the top.

8-10. If a station protector is to function properly, it must be connected to a good ground. The installer must connect the ground wire to the preferred ground if it is available. The following is a list of suitable grounds, placed in the order of their preference:

(1) The cold water pipe of a public or base water system.

(2) The cold water pipe of a private water system, providing the system contains at least 10 feet of buried pipe.

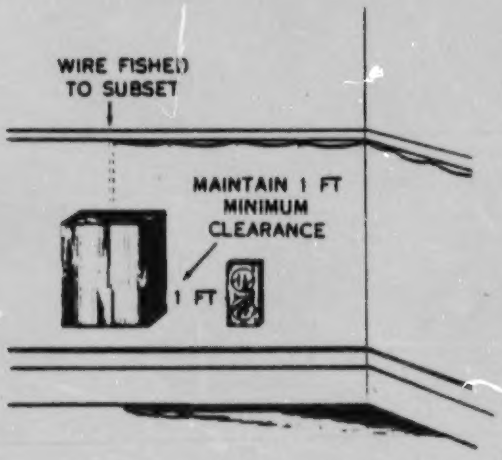


Figure 80. Partially concealed wire run.

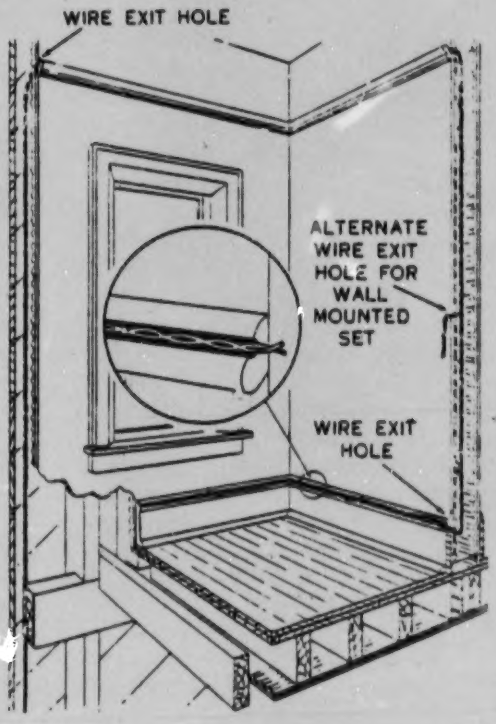


Figure 81. Wire run in molding groove.

(3) A permanently installed metal tank, conduit, or pipe.

(4) A ground rod. In dry and sandy soil, and in extremely cold regions one rod will not provide an adequate ground. In such cases, it may be necessary to use several rods strapped together. When several rods are used, there should be at least 12 inches of space between them. Figure 75 shows two ground rods strappe [illegible]

8-11. There are three sizes of wire available for making ground connections: Nos. 6, 12, and 14 AWG rubber- or plastic-insulated wire. One fuseless protector or three fused protectors may be grounded through No. 14 wire. Two fuseless or five fused protectors may be grounded through No. 12 wire. Any number of equipment protectors may be grounded through No. 6 wire. If a ground rod is used instead of other preferred grounds, a separate rod with separate ground wiring should be used with each protector.

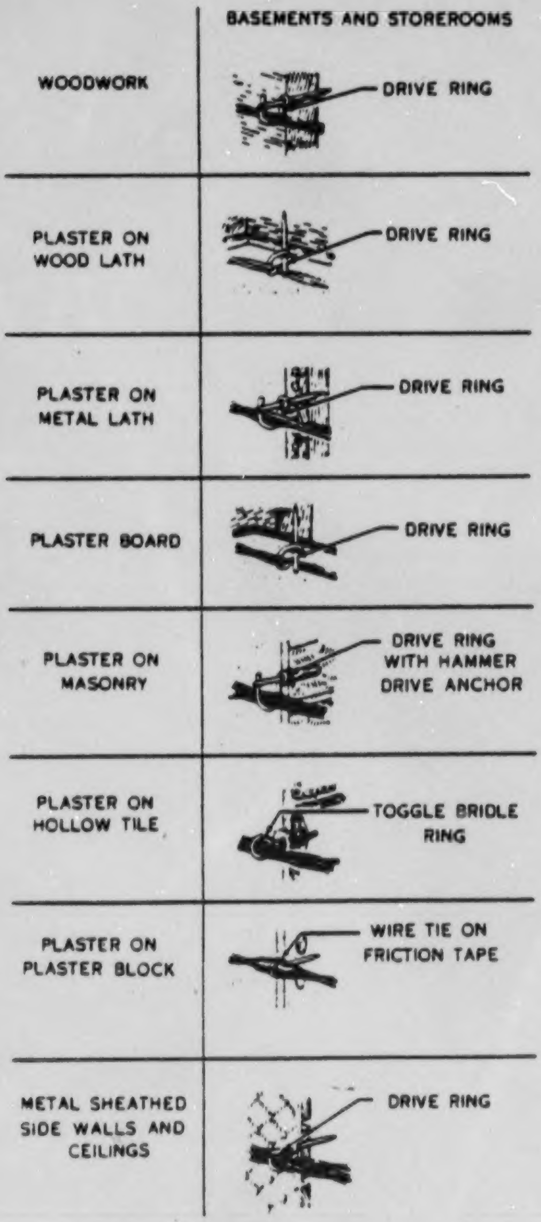

BASEMENTS AND STOREROOMS
WOODWORK
DRIVE RING
PLASTER ON WOOD LATH
DRIVE RING
PLASTER ON METAL LATH
DRIVE RING
PLASTER BOARD
DRIVE RING
PLASTER ON MASONRY
DRIVE RING WITH HAMMER DRIVE ANCHOR
PLASTER ON HOLLOW TILE
TOGGLE BRIDLE RING
PLASTER ON PLASTER BLOCK
WIRE TIE ON FRICTION TAPE
METAL SHEATHED SIDE WALLS AND CEILINGS
DRIVE RING

Figure 82. Typical station wire attachments.

8-12. Good locations are important for the ground and ground clamps which secure the ground wire. Also, it is very important that you follow correct electrical practice in making all ground wire connections. It is just as important to have good ground connections as it is to have good connections at all other points in the circuit. In many circuits, as you will learn in section 15, the ground return is used as part of the ringing circuit.

8-13. The actual location of the ground rod is influenced by breakage or tampering possibilities; do not put it in public alleys and streets or on the sidewalk side of a building. The most suitable place for ground rods is in the basement of a building, as close as possible to the basement wall. After installation, inspect the rod to make sure that the tail wire is not broken.

8-14. Several rules apply to ground wires. Never use spirals or bends greater than a right angle. Also, the ground wire must be one piece. Short sections are allowable only as straps between protectors; splices are allowable only between the ground wire and the TAIL WIRE or ground rod, and

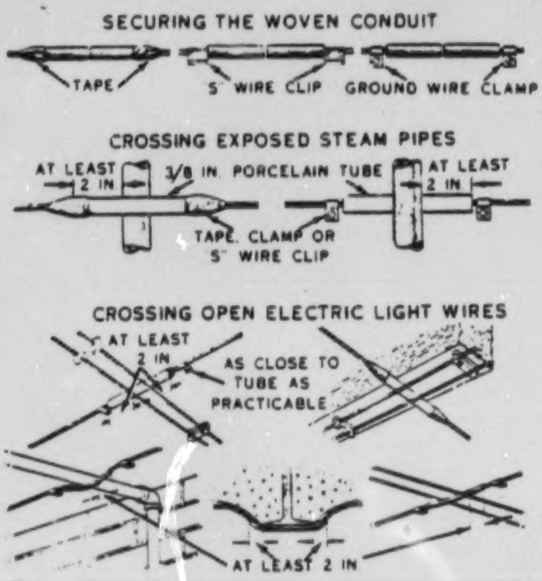

SECURING THE WOVEN CONDUIT
TAPE
5" WIRE CLIP
GROUND WIRE CLAMP
CROSSING EXPOSED STEAM PIPES
AT LEAST 2 IN
3/8 IN. PORCELAIN TUBE
AT LEAST 2 IN
TAPE, CLAMP OR 5" WIRE CLIP
CROSSING OPEN ELECTRIC LIGHT WIRES
AT LEAST 2 IN
AS CLOSE TO TUBE AS PRACTICABLE
AT LEAST 2 IN

Figure 83. Insulating protection for wire.

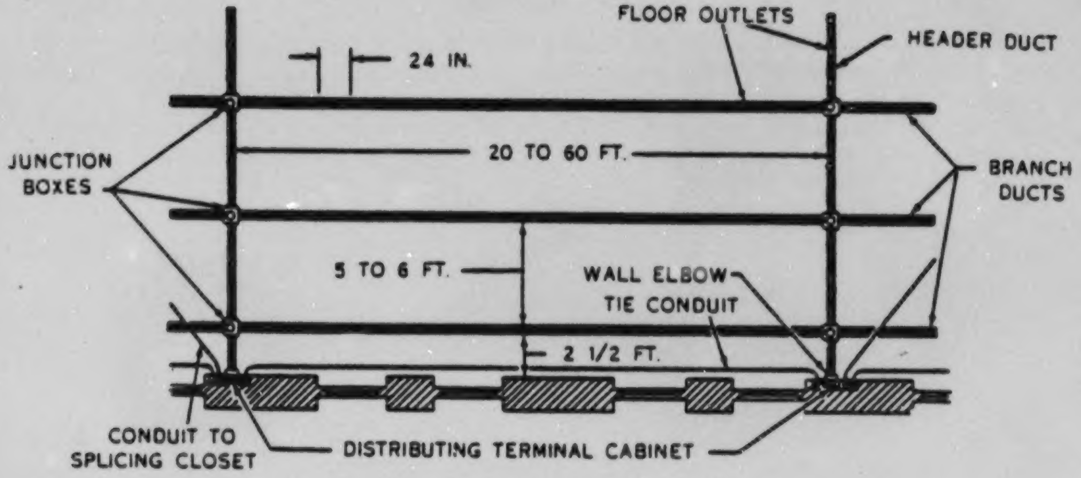


Figure 84. Gridwork underfloor duct.

between the ground wire and a common No. 6 ground wire. Another rule is that the instrument wiring and the protector ground wire must be separated on open runs; that is, inside wires must be placed under separately mounted fasteners. Do not twist inside wires and protector ground wires together. Remember, the ground wire from a protector is not placed in a ring run. Also, the ground wire running to the ground rod is kept at least 6 feet from the ground rods of other services.

9. Inside Wire Planning and Installation

9-1. The installer-repairman must plan the installation of inside wiring very carefully. To do this, he must consider the particular building arrangement as well as the needs of the personnel or organization occupying the building. Since very few buildings are exactly alike and the telephone requirements in different organizations are seldom the same, it is evident that the inside installation must be tailored to the specific situation.

9-2. Selecting the telephone location and insuring a good wire appearance are the first steps in planning any effective installation job. In the following paragraphs, you will learn the criteria and methods you should consider in such planning.

9-3. The type of inside wire, the wire fasteners, the lead in, and any special job requirements should all be considered at the beginning. In other words, plan the inside wire job at the time you plan the drop wire run and select the point of entrance.

9-4. **Telephone and Wire-Entrance Locations.** First, let's consider the telephone location, which should meet the following requirements: The bell should be clearly heard by the user within an area of reasonable size surrounding the telephone location; the telephone should be in a dry place; it should not be near a grounded metallic object, such as a radiator or sink, and never near any electrical applicance. If the telephone cannot be separated from metallic objects, shorten the handset cord so that the user cannot contact the metallic object or electrical appliance when he is using the telephone. Dial sets should be located where there is sufficient light at all times. Also, the telephone set should be accessible for inspection and repair and should be in a location free from excessive vibration. Frequently, you will have to mount wall sets on a backboard. If a combined set is being used, you can usually put the set on the desk. That is, neither the backboard (for the wall set) nor the bell box (for the desk set) need be considered for the combined sets.

9-5. Let us assume that our installation requires an outside mounted protector. At once we are faced with the necessity for making the proper wire entrance. Of course, this entrance location depends on the proposed location for the station apparatus and the required or most advantageous routing of the interior and exterior wire runs. Before selecting an entrance location, make a complete survey of the premises and of the interior and exterior wire routes planned. The survey should disclose whether a built-in entrance (service conduit) has been provided for the building, as shown in figure 76 or 77. When service conduit is provided, use it for the building entrance whenever practicable.

9-6. If built-in service conduit is not provided or is impracticable, you must make an entrance hole as explained previously in this chapter.

9-7. **Appearance and Route of Wire.** The airman installer may find little selection between possible instrument locations within buildings because the telephone must sometimes be used at, or near, a particular desk. However, the inside wire run should follow a reasonably direct path from the point where the wire enters the building to the instrument location and should be free from obstructions. If, by selecting a longer route, you can avoid a concentration of pipes, electrical equipment, or moisture areas which would be damaging to the wire, then by all means do so. That is, select conditions where minimum maintenance will be needed and satisfactory service life will be increased. These should be the deciding factors and are of more consequence than the length of the wire run.

9-8. The appearance of the inside wire run is frequently less important in Air Force installations than it is in commercial installations; however, in every situation a workmanlike job should be sought. Since a concealed wire run will eliminate most appearance problems and some maintenance problems, you may frequently select this type of route. In selecting and using a concealed wire route, you need a working knowledge of building spaces. For example, frame buildings generally have air spaces between the inside wall.

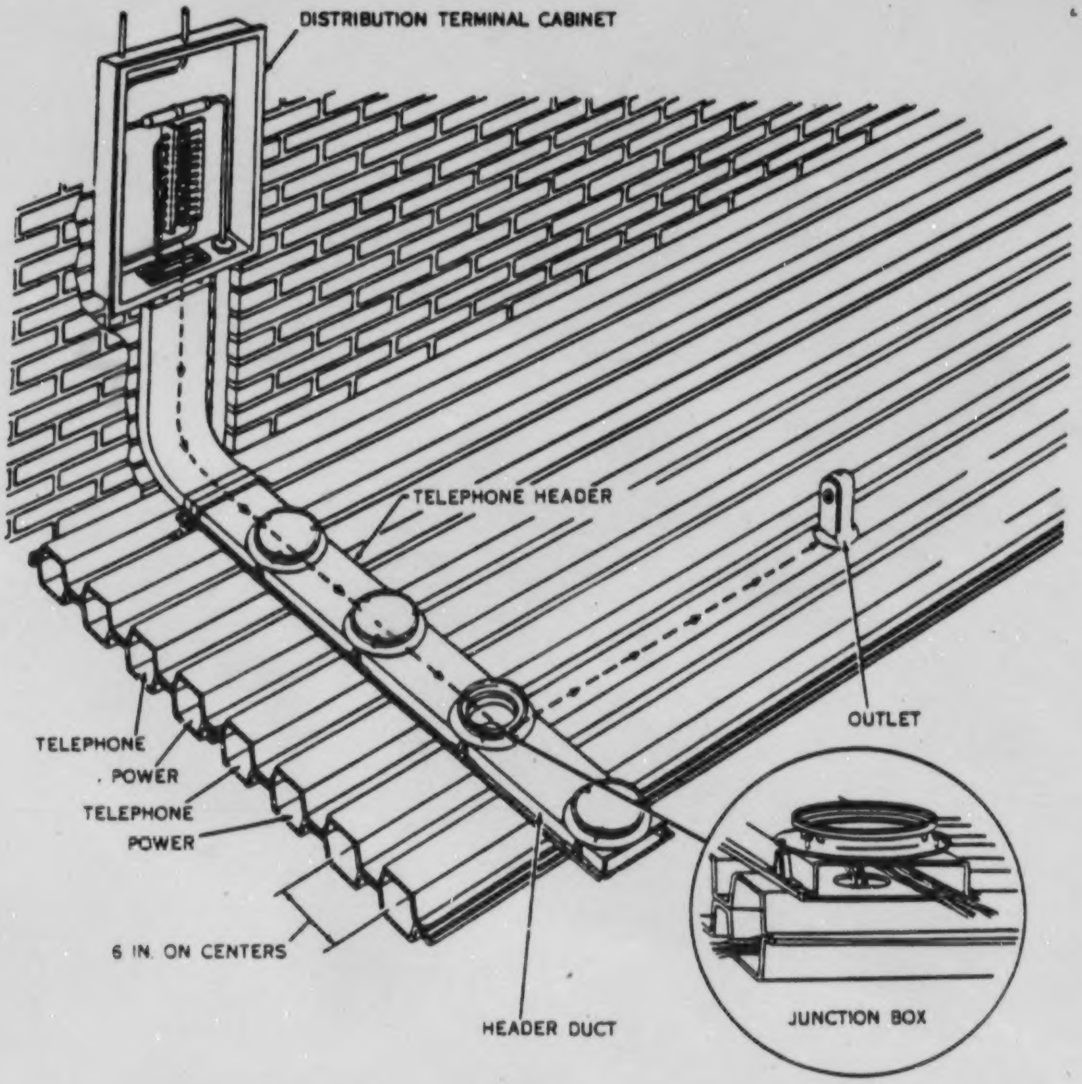


Figure 85. Cellular steel floor type, underfloor duct.

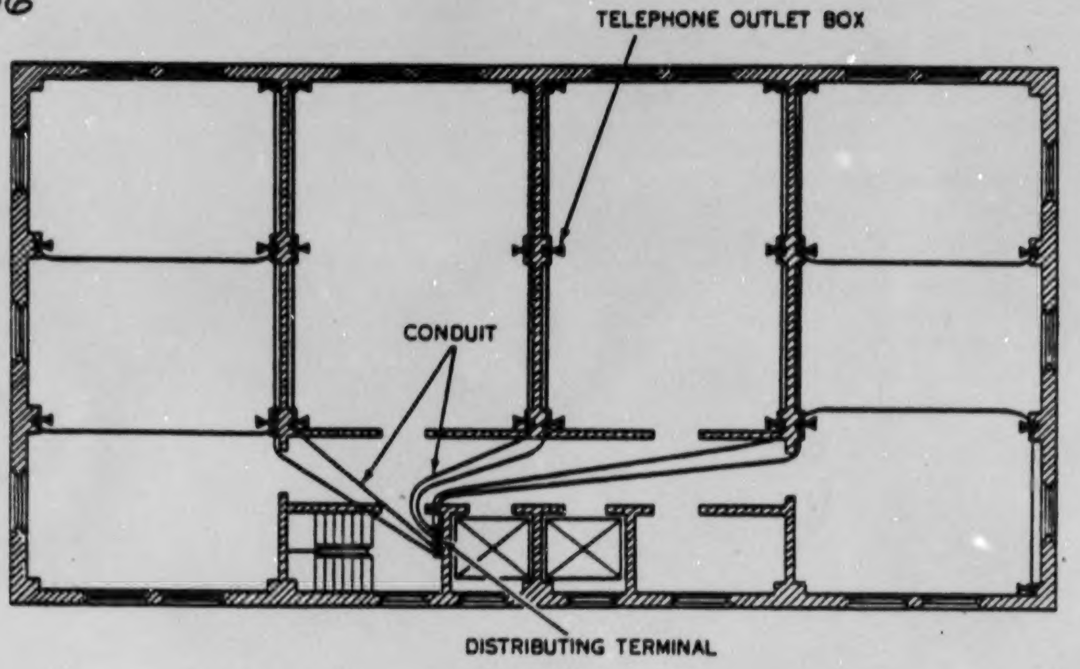

TELEPHONE OUTLET BOX
CONDUIT
DISTRIBUTING TERMINAL

Figure 86. Conduit underfloor from walls.

9-9. For examples of concealed wiring back of building walls, refer to figures 78 and 79. Figure 78 shows concealed wiring in frame construction, and figure 79 illustrates concealed wiring in masonry construction. Where appearance or probability of wire damage is of sufficient importance, you may fish the telephone wire through these spaces; but more rapid installations can be made by following a molding or baseboard. Figure 80 shows a neat wire run concealed for only a short distance. Note in this illustration that the wiring is concealed back of the wall from the molding down to the subset. Note also that the exposed wiring follows the molding along the wall.

9-10. Many Air Force installations are not suitable for concealed wire; therefore, wire runs must usually be made on the surface. Following are several rules that apply for surface runs:

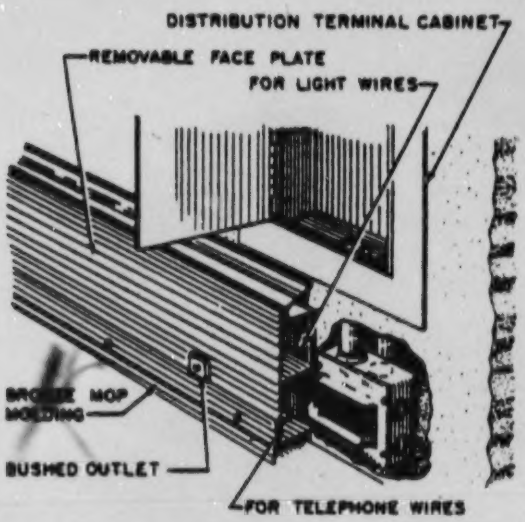

DISTRIBUTION TERMINAL CABINET
REMOVABLE FACE PLATE
FOR LIGHT WIRES
BRONZE MOP MOLDING
BUSHED OUTLET
FOR TELEPHONE WIRES

Figure 87. Metal base raceway.

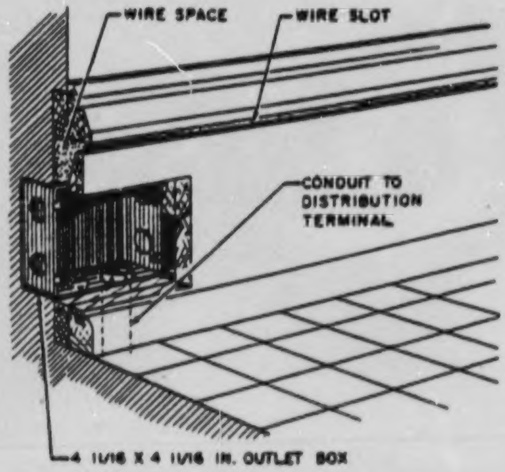

WIRE SPACE
WIRE SLOT
CONDUIT TO DISTRIBUTION TERMINAL
4 11/16 X 4 11/16 IN. OUTLET BOX

Figure 88. Wood base raceway.

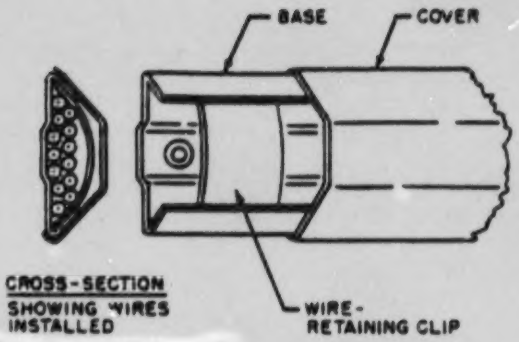

BASE
COVER
CROSS-SECTION
SHOWING WIRES INSTALLED
WIRE-RETAINING CLIP

Figure 89. Metal overfloor duct.

- "Follow the baseboard rather than the ceiling line except in a basement."
- Use wire molding, picture moldings, or raceways when they are available.
- To prevent damage, place the wire in a metal or wood molding on vertical runs where picture or door moldings are not accessible.
- Be sure that the inside wire does not interfere with the operation of windows or doors and that the wire run does not span stair wells or other open places.
- Do not make beam-to-beam runs above work benches or stored boxes unless the wire can be placed where it will not be damaged.
- If joists must be spanned, stay within 3 inches of the wall.

9-11. For an example of wiring in a molding groove, refer to figure 81. As shown in this illustration, the wiring enters an upstairs room at a molding near the ceiling. It follows this molding to a position across the room where it goes back of the wall and down to a lower molding. It then follows this lower molding to a position where it can be connected to a subset. In addition, note that there is an alternate wire exit shown for the connection of a wall-mounted set.

9-12. Location and appearance are not the only factors that determine the wire to be used for an inside wire run. For example, locations where severe moisture conditions may cause wire trouble, such as the area under the building, require the use of a moisture-resistant wire. This

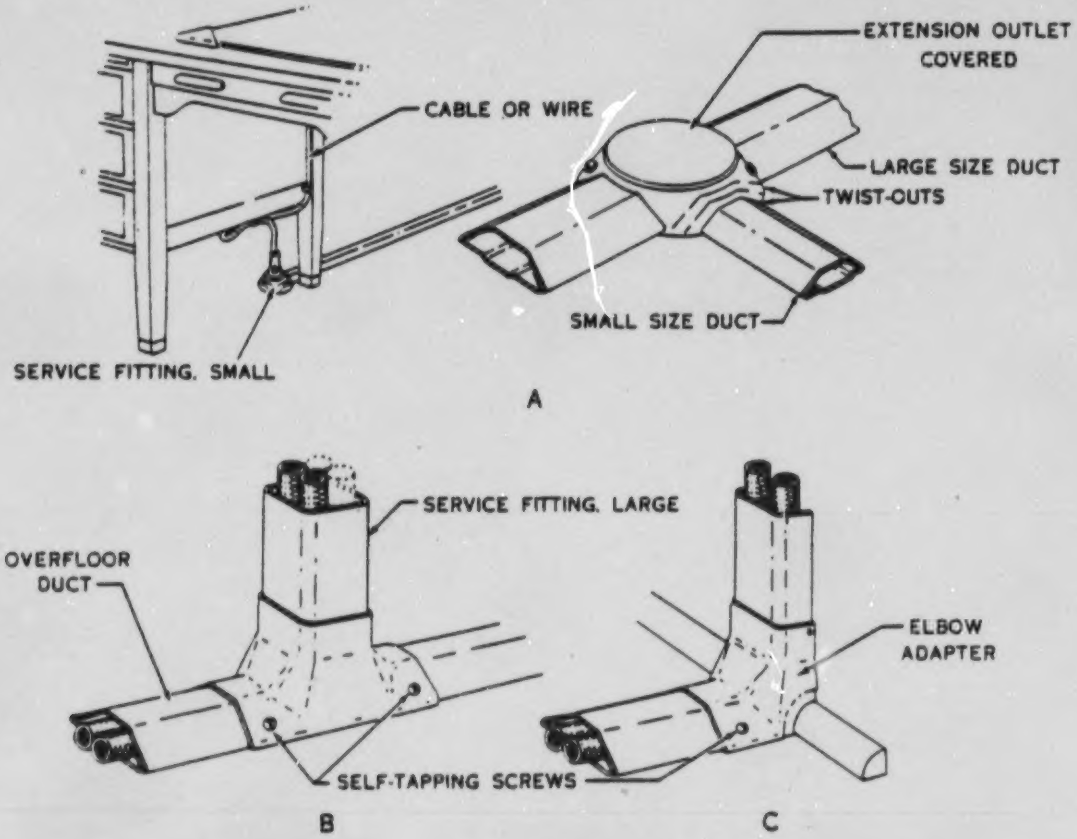

EXTENSION OUTLET COVERED
CABLE OR WIRE
LARGE SIZE DUCT
TWIST-OUTS
SMALL SIZE DUCT
SERVICE FITTING, SMALL
A
SERVICE FITTING, LARGE
OVERFLOOR DUCT
ELBOW ADAPTER
SELF-TAPPING SCREWS
B
C

Figure 90. Metal overfloor duct fittings.

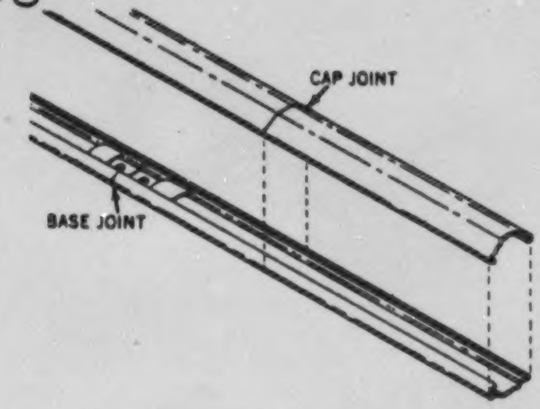


Figure 91. Staggered arrangement of duct joints.

wire may also be used as a substitute for bridle wire. If appearance is very important, use a wire built for appearance, one having a jacket that blends with woodwork or desk coloring. Ivory-jacketed wire is available for light-colored woodwork and brown-jacketed for mahogany or walnut installations.

9-13. **Wire Protection and Attachments.** Wire installation techniques depend upon the job situation. Throughout the wire run, wire must have the proper clearance and protection. If wire is secured to walls or goes through walls, floors, or ceilings, you must use proper fasteners and prescribed protection methods. The fasteners for inside wire are designed to fit almost all situations which you will encounter; however, remember to place the fasteners over studding in the walls and never to fasten wires directly to conduits, pipes, or their supports. Figure 82 illustrates some of the wire attachments used in basements, storerooms, and other areas where appearance is secondary. In finished rooms and offices, discrete cable clamps employing fasteners suitable for the wall surface supporting the wire run are used. In many instances, various types of staples are used in the attachment of inside wiring, including some which are applied with staple guns.

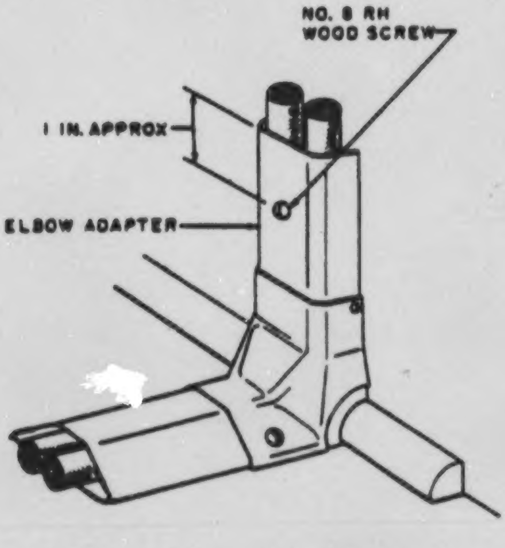


Figure 92. Securing overfloor duct elbow adapter.

9-14. The protection for inside wiring (tape wrappings, porcelain tubes, woven conduits, etc.) is selected to suit the job at hand. Figure 83 shows examples of protection applied for various situations. Woven conduit is used when shaping of the protective conduit is required, as when the wire crosses a pipe or beam. Note the methods used to prevent slipping. Porcelain tubes should be used when crossing exposed steam pipes or open electric wires. Whenever practiccable, a wire run should be above rather than below any water pipe which must be crossed. Water pipes may sweat under certain conditions. You should maintain at least 6 inches clearance between telephone wiring and foreign ground wires; however, since you cannot always do so, the protections shown are used where the wire cannot be separated from other objects by the proper clearance distance.

9-15. Remember that between the point of entrance and the inside-mounted protector, the line wire must not touch nor be capable of moving into a permanent contact with any combustible or electric current-conducting material.

9-16. **Use of Conduit.** Conduit is frequently used for telephone wiring in Air Force buildings; hence you must understand conduit arrangements and know how to run wire in conduit. First, let us consider conduit in general.

9-17. The conduit system should be designed with its primary purpose in mind: to inclose and support the building cables and wiring. Therefore, even if the characteristics of a building indicate the need for a conduit system, a detailed design should not be prepared until the required locations, quantity, and type of service have been carefully determined.

9-18. Building conduit systems not only eliminate the hazards, exposure to damage, and ob-

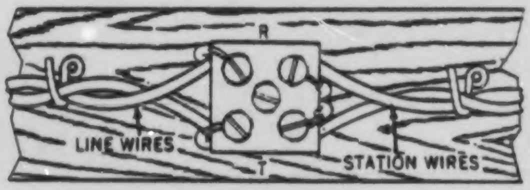


Figure 93. Wiring at connecting blocks.

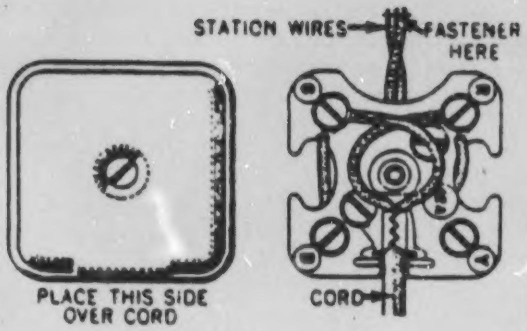


Figure 94. Cord connections.

jectionable appearance of unconcealed cable and wiring but also facilitate the installation of the access to the building cable plant. Thus, future changes in the location and number of telephones are less difficult. Because of these characteristics, conduit systems are particularly desirable for buildings having a large number of telephones; but regardless of the service requirements, conduit should also be installed in buildings or areas where:

- Exposed cable and wire would be subjected to mechanical or electrical damage.
- Exposed cable and wire would constitute a hazard.
- The appearance of exposed cable and wire would be objectionable.

9-19. The above-mentioned characteristics may apply to all or part of a building; therefore, the need for conduit is determined for each area of a building, rather than for the building as a whole. Some buildings are designed and constructed for organizations of known size and activity and are established by building type, provided the building is used as planned.

9-20. If conduit is to be concealed, it should be installed before the building is completed. Although some conduit may be placed after the building is finished or during remodeling, it is more expensive to install and very difficult to conceal. Furthermore, a conduit system added to a completed building may not be as effective as one that is planned and constructed as an integral part of the building. So installation of efficient and economical conduit systems demands the complete coordination of all agencies concerned with construction of the building.

9-21. Basically, there are four general types of building conduit systems: underfloor duct, conduit underfloor-from-wall, base raceway, and molding raceway. These systems protect the conductors from mechanical injury and provide easy access for installation of wiring and connections. They also conceal the conductors whose exposure would constitute a hazard.

9-22. *Underfloor ducts.* Underfloor duct systems are of two kinds—gridwork and cellular steel floor. The gridwork system, shown in figure 84, is made up of parallel header ducts running from distribution terminal cabinets. These parallel ducts are normally spaced from 20 to 60 feet apart. Parallel branch ducts spaced 5 to 6 feet apart run at right angles to the header ducts. Junction boxes are positioned at the intersections of the header and branch ducts. Floor outlets with removable caps are spaced about every 24 inches along the duct runs. Separate conduit is used with this system to carry tie cables between distributing terminal cabinets and splicing closets.

9-23. In the cellular steel floor system, shown in figure 85, the cells or ducts in the floor serve as wiring channels. These ducts are placed on 6-inch centers. Usually, particular ducts are assigned a definite use. For example, telephone wiring may be assigned to the in-between ducts. Thus, the telephone installer may have access to ducts spaced at 12-inch intervals across the floor. Outlet heads may be installed at practically any point along the duct runs. These parallel cells are crossed by header ducts which run to distribution terminal cabinets. Junction boxes are provided in the header ducts.

9-24. *Conduit underfloor-from-wall.* The conduit underfloor-from-wall system, as the name implies, is a network of conduit extending from distribution terminal cabinets to outlet boxes in the walls, columns, or floors of a building. Figure 86 illustrates a typical underfloor-from-wall system. Note how the conduit extends underfloor from a distributing terminal to various locations in the building.

9-25. *Base raceways.* Base raceways systems may be either metal or wood. The metal raceways are merely wall baseboards that contain channels through which wire can be run. (See fig. 87.)

9-26. Outlets are provided at intervals along the face plate of these baseboards. Wooden raceways are also wall baseboards but with a space in the rear through which the wire can be run. (See fig. 88.) A slot between the wood baseboard and the baseboard molding is used for outlets. Conduit from distribution terminals to boxes mounted in the walls behind the base raceways is used with both the wooden and metal raceway systems.

9-27. *Molding raceways.* Molding raceway systems are similar to base raceway systems except that the wires are distributed through concealed channels at the rear of ceiling moldings.

9-28. *Placing wire run in conduit.* When you are required to make station wire runs in buildings equipped with some type of conduit system, trace out the duct runs and locate the outlets which are best suited for your purpose. After this has been done, use the simplest and most direct route for the wire run. NOTE: Make certain that the telephone wires are not placed in the same ducts with wires from other services such as power, intercommunication systems, or electrical light wires.

9-29. Station wiring can usually be placed directly in raceway type building conduit systems. In underfloor systems the wire must be "pulled in." The use of a fishline or tape is usually required to pull wires through conduit. If a fish tape is not available and there are no sharp bends in the duct run, a length of galvanized steel wire is a good substitute. In either case, the fish tape or wire is first pushed through the conduit; the station wire is then attached to it and is drawn into place by removing the fish tape or wire. If the wire is hard to pull in the conduit because of the length of the run or bends in the duct, the wire may be lubricated with Flaxsoap or Carbowax. Only a thin film of lubricant is necessary. Excess amounts, if left in the ducts, will become gummy and tend to clog the ducts. NOTE: Do not use a lubricant on textile-covered wires or cables and never use a mineral oil product as it may deteriorate the insulation.

9-30. *Installation.* Of course, the installation of conduit is largely determined by the conduit type. For example, extensive underfloor installations can be made only while the building is being constructed, but overfloor duct systems may be placed in a completed building; and, in general, where underfloor conduit has not been provided, overfloor duct may be used. Either metal or rubber overfloor duct may be used, depending on the floor surface. The following paragraphs describe metal and rubber overfloor duct and discuss the uses and installation of each type.

9-31. Metal overfloor duct (fig. 89) consists of a base with sloping sides and a snap-fit cover and is available in two sizes, each in 5-foot lengths. The smaller size will accommodate five pairs of four triple-plastic-jacketed station wires; the larger size will accommodate two 26-pair inside wiring cables. Two fiber wire-retaining clips are furnished with each length.

9-32. Fittings equipped with triple twistouts, provide any necessary outlets, elbows, and junctions in the duct run. Removal of the smallest twistout provides the proper size opening in the fitting for the insertion of the smaller size metal duct; and removal of all three twistouts provides a large enough opening for the larger size metal duct. One is used under the desk to run the cable or wire up through the extension outlet by the use of a service fitting. Figure 90, B, illustrates a large service fitting which is used when a number of wires or cables are involved. The elbow adapter, shown in C of figure 90, can be used when it is necessary to run wires up a wall.

9-33. Metal overfloor duct is used on rough floor surfaces where holes in the flooring for the fastening devices are not objectionable and where secure fastening to the floor surface is desirable. For example, small size duct is installed as follows:

(1) Run the base of the duct along the desired wire route. Connect the duct to the proper fittings by inserting it in the tongues provided in the bases of the fittings. If the length of the duct run exceeds 5 feet, add additional unit lengths of duct as required. When necessary, cut the duct to proper length with a fine-tooth

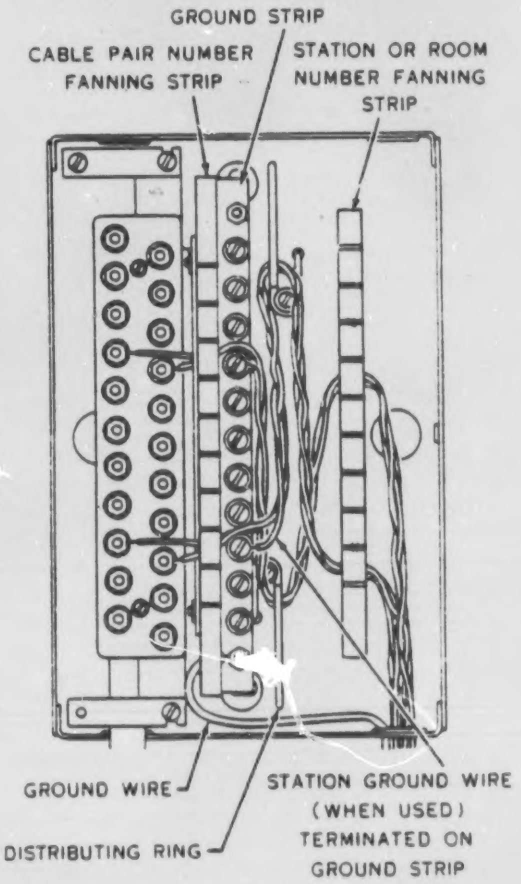

GROUND STRIP
CABLE PAIR NUMBER FANNING STRIP
STATION OR ROOM NUMBER FANNING STRIP
GROUND WIRE
DISTRIBUTING RING
STATION GROUND WIRE (WHEN USED) TERMINATED ON GROUND STRIP

Figure 95. Typical distribution terminal.

hacksaw blade and smooth the cut edges with a file. For better rigidity, arrange adjoining lengths of duct so that the joint of the duct caps is removed from that of the duct bases (fig. 91).

(2) Fasten the base to the floor with wood screws, wood screws in screw anchors, or hammer drive anchors, your choice depending on the type of flooring. Also, if the floor or baseboard is uneven and an elbow adapter does not fit snuggly, secure the top portion of the adapter to the baseboard with a No. 8 roundhead wood screw, as shown in figure 92. Drill a hole for the screw in the center line of the fitting about 1 inch from the top.

9-34. **Station Wire Termination.** Once the station wiring is complete all that remains to be done in the building is to make the necessary connections. Generally, the station wiring is terminated at protectors, connecting blocks, or distribution terminals. Information about the use and connection of protectors was given earlier in this chapter. Therefore, let us now consider connecting blocks.

9-35. *Connecting blocks.* Connecting blocks are normally used in three different ways:

- To terminate (connect) the line and station wires near the building entrance when a protector is not required.
- To bridge station wiring.
- To connect station wiring and telephone cords.

9-36. Connecting blocks may be located on desks, tables, baseboards, beams, windows, and door frames in a substation installation. Since splices are avoided in the installation, the connecting block is doubly necessary. The location of the connecting block, like that of other portions of the installation, should be selected for accessibility and safety. Place the connecting block where neither it nor the wiring which runs to it will be a source of trouble.

9-37. In figure 93 you see a simple type of connecting block used as stated in paragraph 9-35, above. Be careful when connecting the wires so that they are tip to tip and ring to ring.

9-38. When the telephone is on a desk, a connecting block similar to the one shown in figure 94 is frequently mounted on the desk with the telephone cord brought out through a slot or

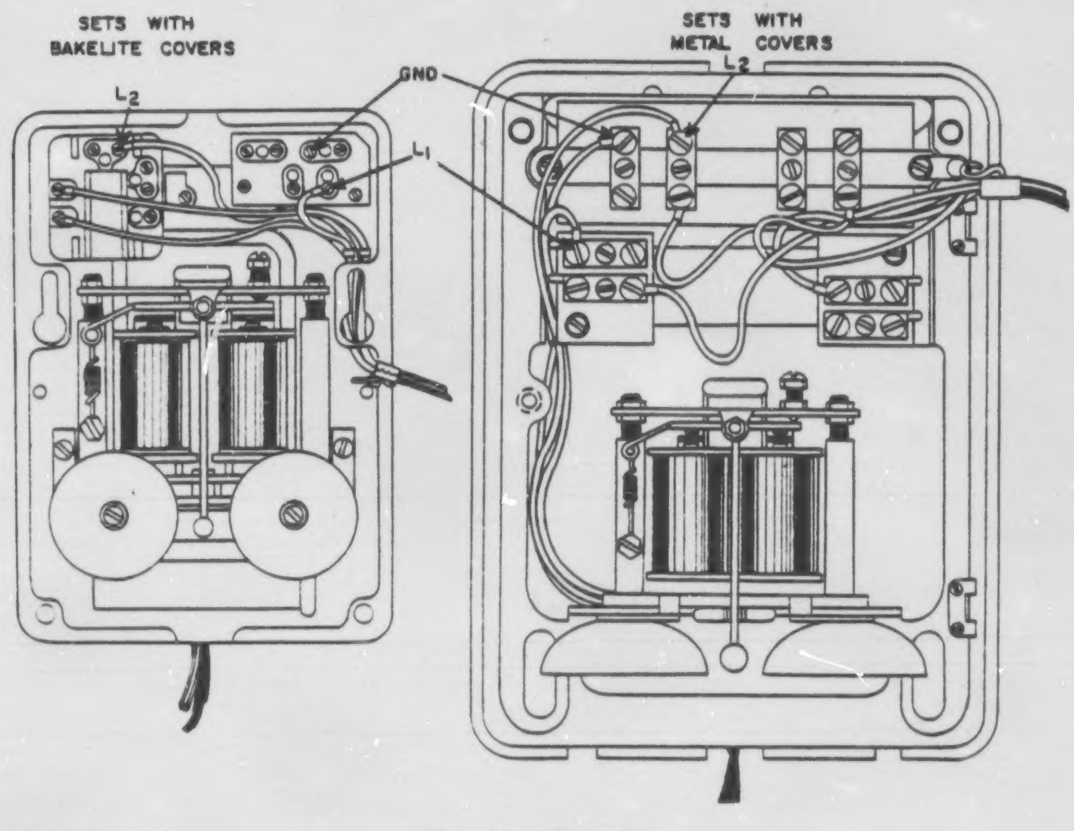


Figure 96. Subset wiring.

hole in the desk top and within a few inches of the front of the desk. If this arrangement is not possible, mount the connecting block on the side of the desk. The type 42 block is shown with the cover removed and indicates the means by which wires are brought into the connecting block. Notice that the station wire is wound around the block so that a strain on the wire will not tend to pull it loose from its terminal. Also, the telephone cord coming into the connecting block is arranged so that a strain will not cause a direct loosening of the connection. While observing figure 94, you should also note that the block terminals are identified by the letters "R," "G," "B," and "Y." These letters are used to identify the terminals for the connection of station and cord wiring. Normally, these letters signify the colors of red, green, black, and yellow. The ring and tip leads are usually connected to the R and G terminals on the block. However, to terminate any telephone equipment you must connect it in accordance with the color code and the circuit diagrams for the piece of apparatus concerned to insure proper operation.

9-39. *Distribution terminal.* In buildings where a large number of telephones are installed, such as offices, apartment houses, etc., distribution terminals are often used for terminating the inside cables. This type of terminal arrangement is illustrated in figure 95. While observing this type of terminal, note that fanning strips are provided for cable pair identification and for the identification of phone wires by either station or room numbers. Also note that a ground strip is included which provides a ground terminal for each phone in the building.

9-40. When a distribution terminal is provided, you will find it advantageous to connect the station wiring directly to the terminal. When such connections are made, you should leave enough slack in the wire so that it can be terminated at any binding posts in the terminals. This wiring arrangement is usually accomplished by routing the wire through the distributing ring farthest from the assigned set of binding posts, as shown in figure 95.

9-41. **Installation of Station Apparatus.** After the station wiring is installed and terminated, we are then ready to connect the telephone set and any other auxiliary equipment. Auxiliary telephone devices such as signaling equipment, switching keys, etc., are normally called station apparatus.

9-42. *Subsets.* Combined subsets are the easi-

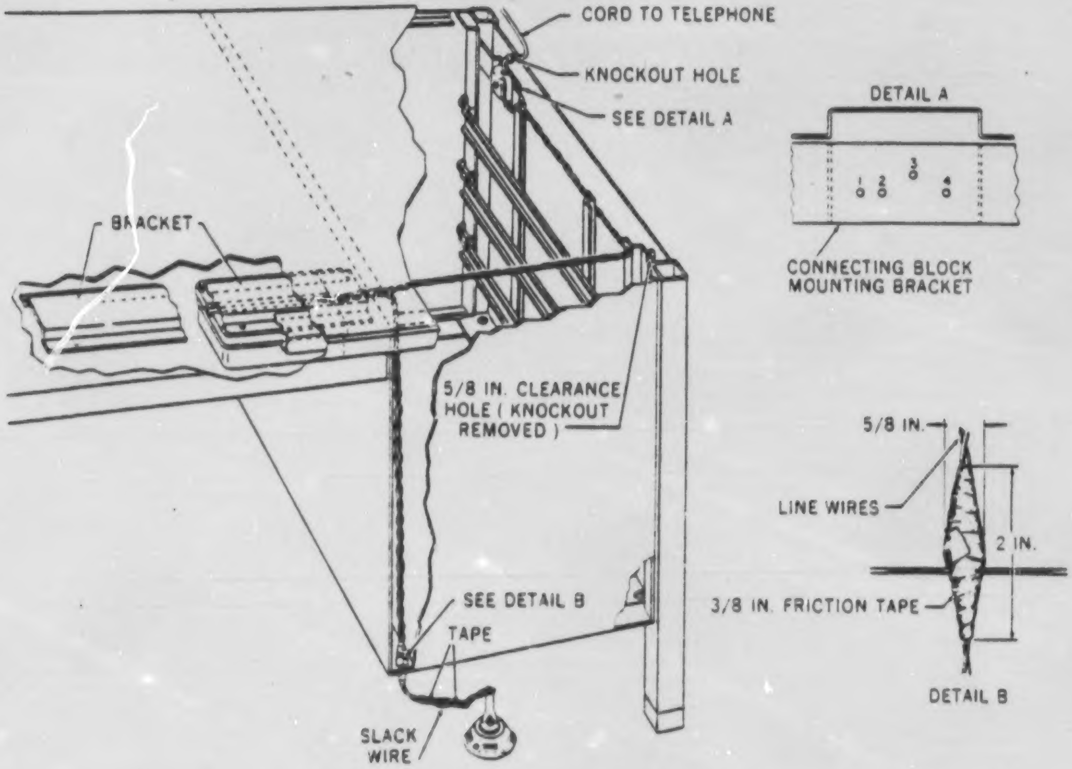


Figure 97. Typical wiring facilities for desk.

est items to install, because in most cases it is only necessary to connect the proper wires to the proper terminals. Wire fasteners are not required if the subset is placed where no strain will be placed on the conductors, or if the wire is entirely concealed as it comes to the subset. Remember, the cord connections and the inside wire conductors are connected together at the terminals of a connecting block mounted on the desk, wall, etc. Each telephone should be connected to the line in accordance with the specific wiring diagram instructions furnished by the manufacturer. Figure 96 shows terminations of the hand set cord and the line within two subsets.

9-43. *Desk type telephone*. In most cases, it is not good practice to attach wiring to desks. In situations where it cannot be avoided, you should allow at least 1 foot of slack wire between the floor outlet or last wall attachment and the first desk attachment. This wiring arrangement allows the desk to be moved slightly without damaging the wire. If a connecting block must be mounted on the desk and the desk panel is less than ⅜ inch thick, the panel should be built up with a wooden backboard to increase its strength. A wire run on a desk must be neatly installed and concealed as much as possible. If it cannot be concealed, be sure that it is neat because a sloppy wire run is noticed by everyone. To help provide concealment, the wire should be placed in the angle formed by the top and sides of the desk or in the angle formed by the legs and panels of the desk. You should use inside wiring nails or staples for attaching wire to the desk.

9-44. Some types of desks are equipped with wiring facilities. On metal desks equipped with wire runs, the wire should be protected at the entrance and exit holes by installing the soft, rubber grommets provided or by placing several wrappings of tape on the wire. Figure 97 illustrates the wiring arrangement on a desk equipped with wiring facilities.

9-45. *Signaling equipment*. In the installation of telephone equipment, you may come across situations when normal station ringers do not meet the signaling needs of the subscriber. Also, when installing telephones on party lines, it may be necessary to connect the phones for various types of selective ringing. In installations where noise makes it difficult to hear the telephone ring, it may be necessary to install such apparatus as extension ringers, loud ringing bells, buzzers, or lamp indicators. Also, when the individuals on party lines do not wish to hear the ringing for other parties on the line, it may be necessary to install a selective ringing system of some sort. Extension ringers, loud bells, and selective ringing systems are discussed in Chapter 4 of this volume. Therefore, we will not discuss their operation at this time.

9-46. *Transfer keys*. Transfer keys are normally used in small installations where it is impractical to install complicated key systems and it is desirable to have more than one line connected to a single telephone set. Transfer keys may be used where it is desirable to have one party answer all incoming calls and, of course, for transferring the calls to other persons. There are numerous types of keys available, both pushbutton and lever types. Regardless of which type you install, they must be located where they are the most satisfactory to the user from the standpoint of appearance and convenience. The usual practice is to mount the keys at the side of the desk or table leg. When connecting a transfer key, it must be terminated in accordance with the instructions for the type of apparatus used.

9-47. *Special equipment*. The installer-repairman may be called upon to install special equipment such as explosion-proof telephones, recording devices, and other specially designed apparatus.

9-48. Explosion-proof sets are intended for use at all locations where the atmosphere contains gases or vapors capable of exploding. These sets are constructed so that all parts of the apparatus which might cause a spark are completely inclosed. Rigid conduit must be installed with these explosion-proof telephones. The conduit must run from the set to a point outside the hazardous area and all openings in the conduit must be sealed with an approved sealing compound. Generally, normal installation practices may be followed except that a line switch must be included to discharge the condensers whenever it is necessary to open the telephone set for servicing.

9-49. There are numerous recording devices manufactured that can be placed at the subset to make recordings. Basically, there are two types: an induction type that merely requires an ac power source and a directly connected type that must be wired across the telephone line. In any case, such devices are accompanied by complete instructions for installation. Recorders must be wired, however, to meet certain requirements: One of these is that there must be a "beep" signal applied to the line whenever the recorder is in use. Follow the instructions furnished with special equipment and you should have little trouble with its installation.

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9-50. The workbook contains a number of questions designed to assist you in reviewing the material discussed in this chapter. It is to your advantage that you do these exercises before turning to Chapter 3, where we shall complete our explanation of the installation by telling you how to connect the drop wire to the telephone line or cable terminals.

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Station Termination and Testing

IN CHAPTER 2 we were concerned with the attachments used in the telephone substation area and with the installation of inside and outside building wiring, telephones, and auxiliary telephone devices. Once you have completed the installation of the building runs and station apparatus, you can then complete the connection to the telephone line or cable terminals.

2. To complete the connection from the building to the terminal-can you must first raise the drop wire into place and attach it to the pole, providing the proper amount of sag. Secondly, you must connect the drop wire to the assigned terminal connections. And finally, after all of the connections have been made, you must test the completed installation for proper operation. This chapter tells you how to make the final connection and describes the necessary tests which insure satisfactory operation.

10. Cable Terminations

10-1. Before you consider drop wire termination, refer to figure 2 and recall that the drop wire extends from the building to the terminal pole and that it is connected to terminals inside of the terminal-can. These terminals are connected to cable pairs which extend through the cable to equipment at the central office. So in reality, when you connect the drop wire to terminals in the terminal-can, you are connecting the subset installation to equipment at the central office.

10-2. **Procedure.** The procedure for wire termination is relatively simple—it requires bringing the wire from the building to the terminal pole, placing it with the proper sag, and completing good electrical connections. The general practice in placing span runs is to work from the first building attachment out to the terminal pole. The span may run directly to the terminal pole; or to miss trees and other objects the span may first run to an intermediate pole or to a span clamp mounted on an aerial cable suspension strand. A typical procedure for placing a span directly to a terminal pole is given in the following subparagraphs and is essentially the same in all cases.

(1) Place the drop wire reel assembly on the ground close to the building, as shown in figure 98. Arrange the reel so that the wire pays out from the bottom.

(2) Make sure that the building run is already completed.

(3) Carry the drop wire reel assembly out to the terminal pole. Pay out the wire on the ground, allowing sufficient slack for the wire to lie flat on the ground. Place the drop wire reel assembly next to the terminal pole. If the drop wire crosses a roadway, remember to take any precautions

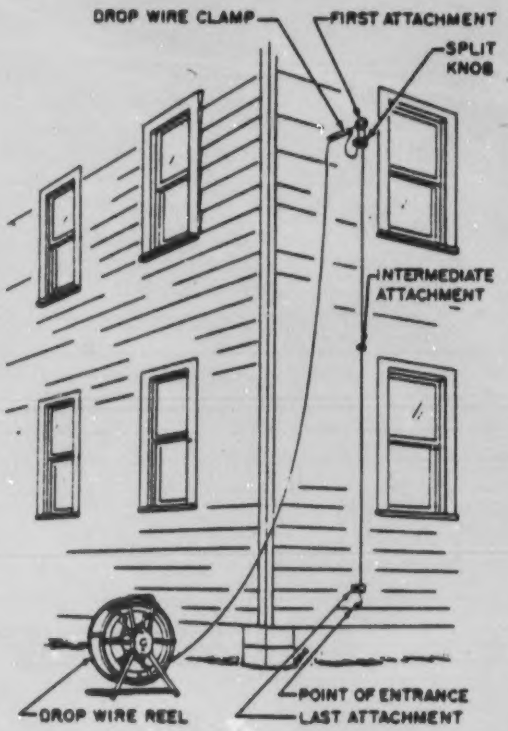

Figure 98. Reel arrangement for paying out drop wire.

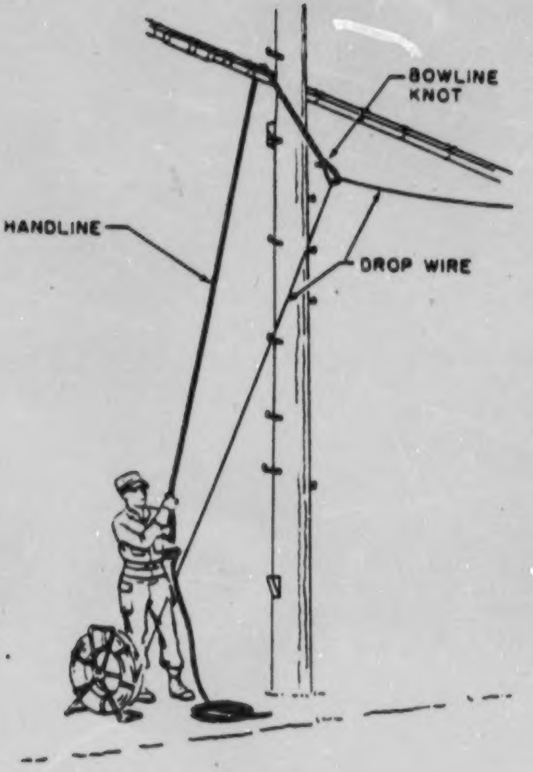

Figure 99. Raising drop wire.

necessary to protect it from being run over by passing vehicles. If the wire is damaged, however, inspect it and replace any damaged portions.

(4) Climb the pole and install a drive hook to support the drop wire. On aerial cable poles, when you can throw a handline over the suspension strand, you may install the drive hook later. At locations where traffic is heavy, install the drive hook before the other placing activities are begun.

(5) Place the handline over the drive hook. Adjust the handline until both ends rest on the ground.

(6) Descend from the pole. Tie the end of the handline that is nearest the building to the drop wire, using a bowline knot.

(7) Adjust the brake of the drop wire reel assembly to provide a drag on the drop wire and to prevent the reel from spinning freely.

(8) Take up on the free end of the handline and slowly raise the drop wire to the drive hook or suspension strand (fig. 99).

(9) Secure the drop wire in this position by tying the free end of the handline to a pole step or to the base of the pole with a clove hitch (fig. 100).

(10) Climb the pole. If the drive hook was not previously installed (step 4), install it.

(11) Pull up the drop wire to the desired sag. Attach a drop wire clamp to the drop wire. Place the loop of the drop wire clamp over the drive hook.

(12) Remove the handline from the drop wire. Cut the drop wire at a point that will provide enough wire to run from the drive hook to the cable or drop wire terminal.

(13) Install the necessary intermediate pole attachments and run the drop wire to the cable terminal or to the drop wire terminal. Terminate the drop wire.

10-3. **Sagging.** Now let us consider some principles for the preceding steps. For example, clearance requirements, appearance considerations, and the possibility of damage from swinging contacts with other wires or obstructions will determine the maximum sag that may be placed in a drop wire span. Normal practice is to sag the drop wire at approximately (but not less than) the minimum sag given in table 1. These stringing sags will provide a favorable operating tension in drop

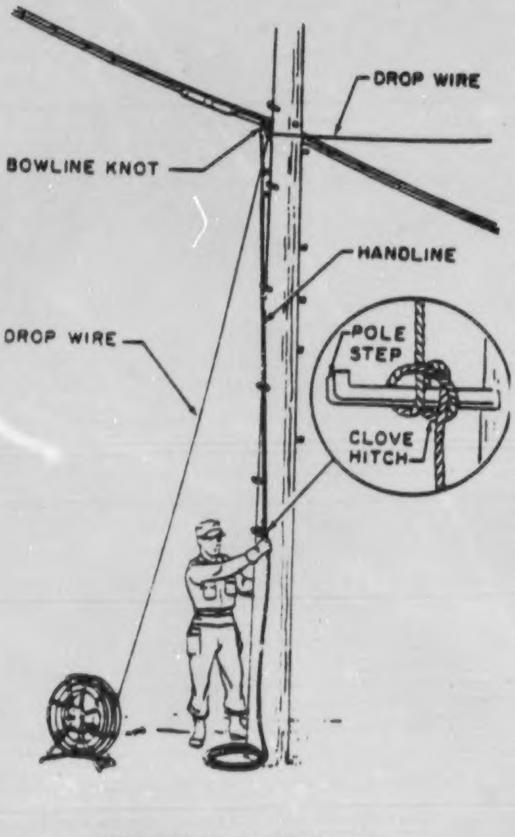

Figure 100. Securing handline.

TABLE 1
MINIMUM SAGS FOR DROP WIRE SPANS

SPAN LENGTH (FT)	STRINGING SAG	APPROX. FINAL UNLOADING SAG FOLLOWING STORM LOADING	SAG INCREASE FROM STRING TO FINAL CONDITION
HEAVY LOADING AREA			
50 (or less)	0 ft 6 in	0 ft 6 in	
75	1 ft 0 in	1 ft 0 in	
100	1 ft 9 in	2 ft 0 in	0 ft 3 in
125	2 ft 10 in	3 ft 4 in	0 ft 6 in
150	4 ft 0 in	4 ft 10 in	0 ft 10 in
175	5 ft 6 in	6 ft 7 in	1 ft 1 in
200	7 ft 0 in	8 ft 6 in	1 ft 6 in
225	9 ft 0 in	10 ft 10 in	1 ft 10 in
250	11 ft 2 in	13 ft 4 in	2 ft 2 in
MEDIUM AND LIGHT LOADING AREAS			
50 (or less)	0 ft 6 in	Same as Stringing Sags	No Increases
75	1 ft 0 in		
100	1 ft 9 in		
125	2 ft 10 in		
150	4 ft 0 in		
175	5 ft 6 in		
200	7 ft 0 in		
225	9 ft 0 in		
250	11 ft 2 in		

wire spans and still maintain required ground clearance under usual construction conditions. At these minimum sags, the stringing tension will be approximately 30 pounds. The table has been compiled to cope with the normal weather conditions experienced in various parts of the country. Figure 10 illustrates the storm loading district map used to determine which portion of Table 1 is used to calculate the proper stringing sag for a drop wire span. In areas where high winds, freezing rains, and wet snows are common, the upper part of the table sets the sag. Where milder weather is experienced, the lower portion of the table is used. Note how a heavy load of ice and snow will stretch a span, thus increasing the amount of sag.

10-4. The proper stringing sag is added to the drop by finding the amount on the table and measuring down that amount from the first attachment on both the building and the pole. Sighting from the marked point on the pole to the marked point on the building will indicate the amount of sag. If any portion of the span extends below the line of sight, the sag exceeds the minimum requirement. When, because of clearance or separation requirements or obstructions in the span run, you cannot place the minimum sag in the proposed span run, you must usually provide protection for the drop wire wherever wire damage may occur between the building attachment and the terminal.

10-5. In general, the terminals used with aerial cable installations are as shown in figures 102 and 103. In figure 102 the terminal is shown mounted on the terminal pole, and in figure 103 it is shown attached to the cable. With either type of installation, cable pairs are brought into the terminal unit and attached to the back of the terminals at the time of cable installation. This, of course, is done by cable installation personnel

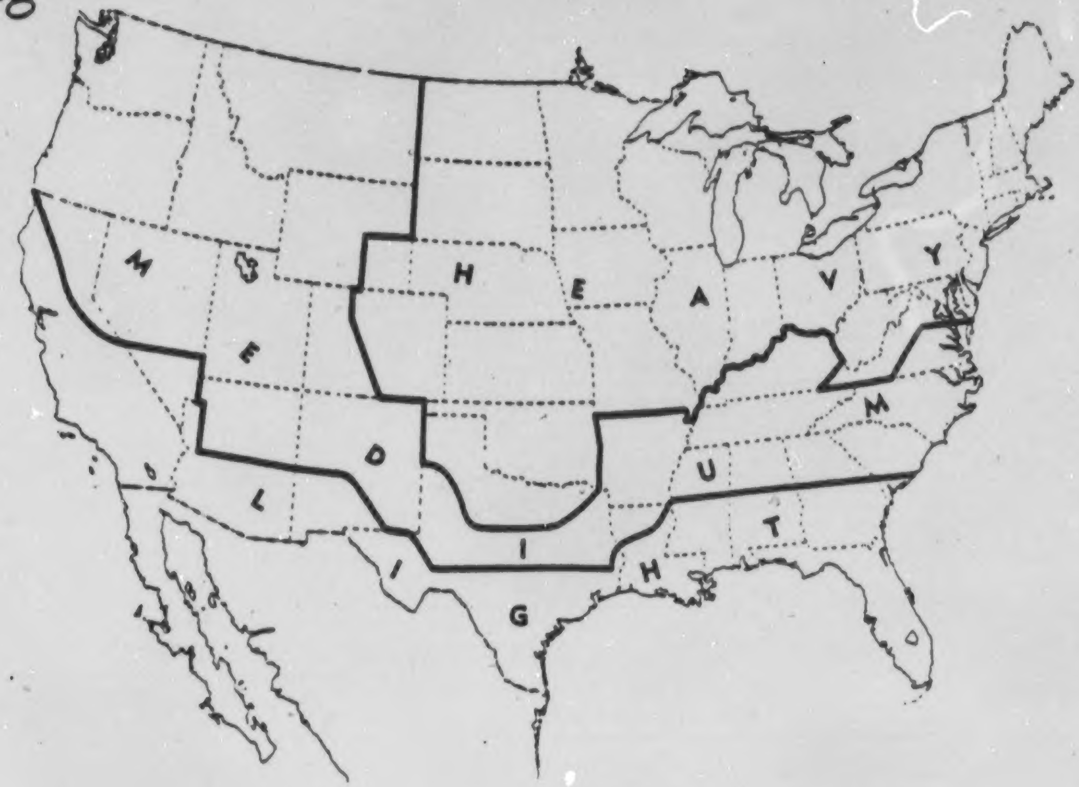

Figure 101. Nationwide loading zones.

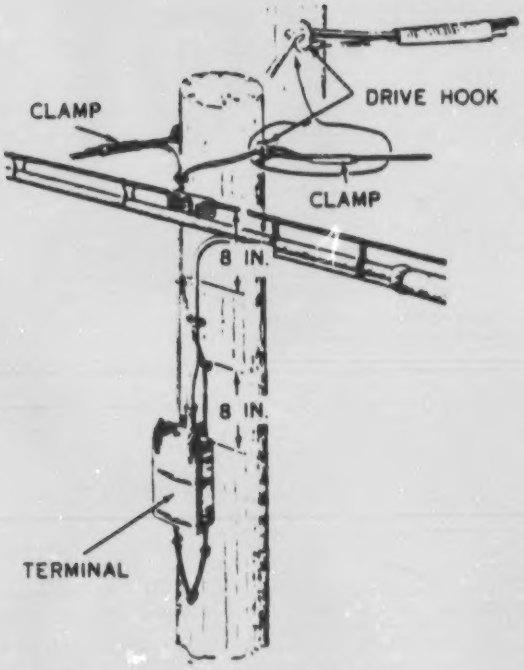

Figure 102. Terminal zone on pole.

who are responsible for terminating the cable. The installer-repairman is not normally concerned with the connection of cable pairs to the terminals, but he is concerned with the connection of drop wire leads to the terminals. As a matter of fact, he must connect the drop wire leads to specific terminals as specified by the installation work order. He must do this to connect the subset which he is installing to a cable pair which extends to available equipment at the central office.

10-6. Some of the most recent outside plant cable installations include polyethylene sheath and conductor insulation. The use of this material permits a new development in terminating wires through the use of a "ready-access" distribution terminal. Some of the features that are a part of this terminal are given in the following paragraph.

10-7. The ready-access cable terminal has three parts: a molded neoprene rubber cover which is weatherproof; a terminal base which consists of two metal strips with hangers which include 24 numbered entry points; and a terminal block which comes with attached cable that is to be connected by sleeving to the incoming cable.

The terminal block uses a different color code than that used on the older terminals. The tip binding posts are from left to right and bear the colors orange, white, brown, white, blue, and red. The ring binding posts carry the colors from left to right: white, blue, white, green, white, and slate. Each ready-access terminal unit can support four of these terminal blocks which can terminate 24 pairs.

11. Terminal Wiring

11-1. After the span run has been pulled up and sagged, the drop wire must be terminated at the terminal. This requires that intermediate attachments be placed on the pole between the drive hook and the terminal and that the drop wire be properly connected. To enable you to become thoroughly familiar with the work in this area, let us examine the terminal zones shown in figures 102 and 103. This area is very important to the installer who is connecting the drop wire. A primary requirement for this zone is that new work be done properly and that any old plant installation in this area be inspected every time the installer is working at or near it, because the terminal zone is a potential trouble area. As shown, the zone generally includes the terminal and about 4 feet of cable on either side of the pole. Within this area the cables, wire, terminal-can, or any other part of the telephone plant are subject to damage while the connections are being made for installation. For instance, the cable sheath may be punctured by climber gaffs, or the terminal tail is likely to develop trouble where it attaches to the can or where it bends. Always check the underside of the sleeve seal, which is a key place to look for holes or cracks in the wiped joint.

11-2. **Terminal Zone Precautions.** Trouble in a terminal zone can sometimes be spotted by making a visual inspection from the ground; therefore, make a practice of inspecting the terminal zone if you are walking past any terminal pole. Such inspection may reveal many poor installation practices. You can observe drop wire clearance, pole attachments, broken or leaning poles, improperly supported lines, loose lines, missing cable rings, and interference from trees. If you see a difficulty that you cannot correct at the time, you should report it to your supervisor or the wire chief so that

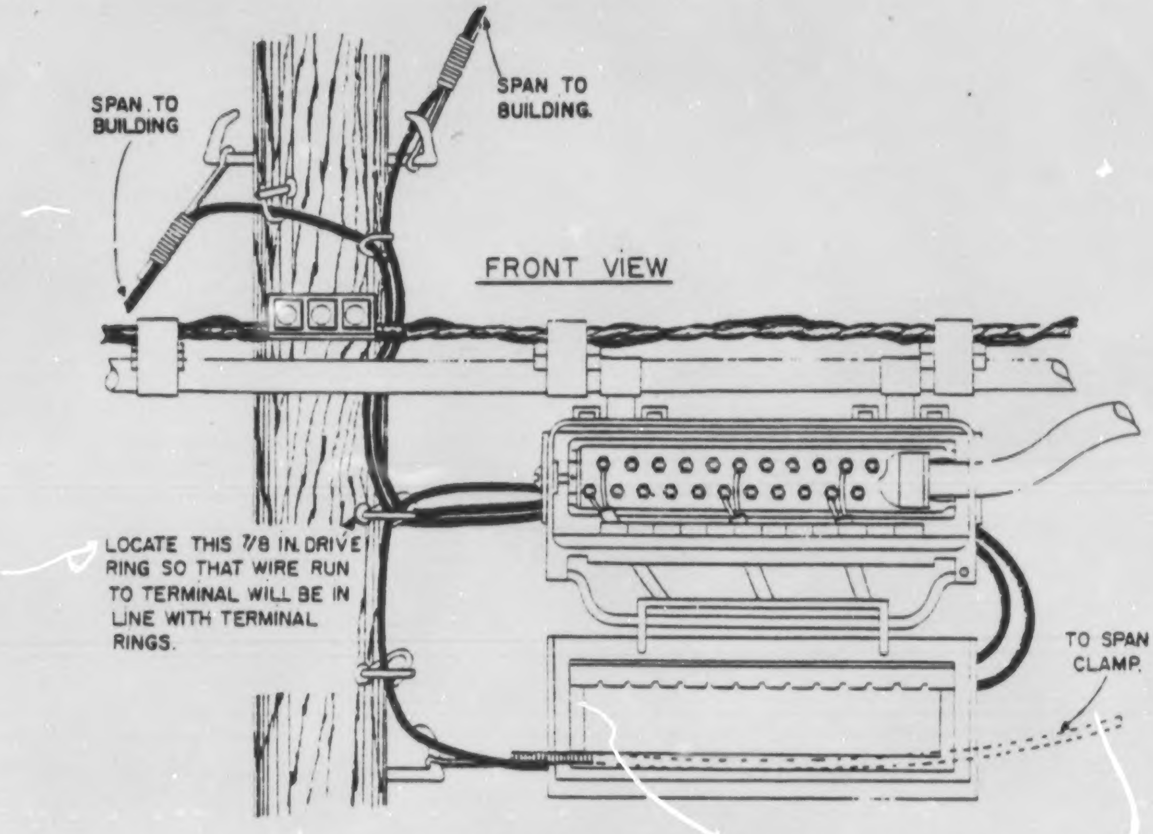
SPAN TO BUILDING
SPAN TO BUILDING
FRONT VIEW
LOCATE THIS 7/8 IN. DRIVE RING SO THAT WIRE RUN TO TERMINAL WILL BE IN LINE WITH TERMINAL RINGS.
TO SPAN CLAMP.

Figure 103. Front view of sheath-mounted terminal installation.

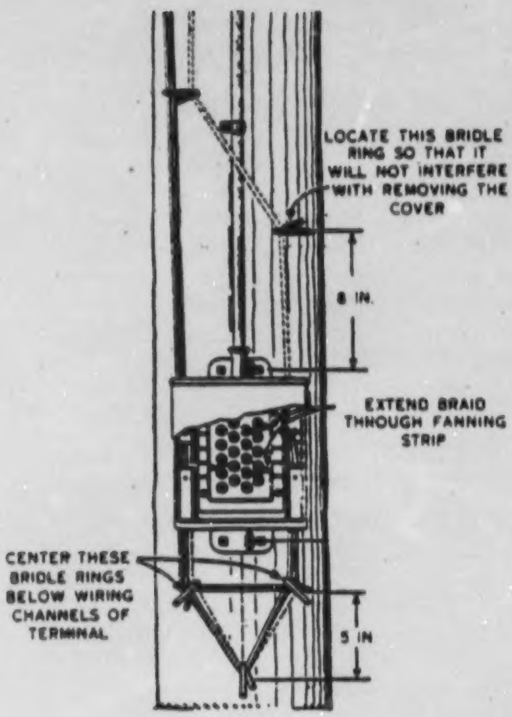
LOCATE THIS BRIDLE RING SO THAT IT WILL NOT INTERFERE WITH REMOVING THE COVER
8 IN.
EXTEND BRAID THROUGH FANNING STRIP
CENTER THESE BRIDLE RINGS BELOW WIRING CHANNELS OF TERMINAL
5 IN

Figure 104. Pole-mounted terminal.

maintenance can be performed as soon as possible.

11-3. The installer or lineman who intelligently makes temporary repairs within the terminal zone is an asset to his organization. A defect which can be cleared immediately, for example, an open circuit caused by a loose connection at the terminal may require only a cleaning at the terminal and a tightening of the lugs with your fingers or a pair of pliers. When complete repair is impossible, you may prevent interruption of communications by an improvised repair, such as wrapping the cable with tape, if you find small holes in the sheathing or seal. Your report to the wire chief will indicate what has been done and will allow him to schedule the permanent repair procedures.

11-4. The wiring at terminals at the pole end of the drop wire run requires effective connections and a neat appearance. Figure 102 shows a complete terminal installation and figure 104 shows a closer view of wiring, including the run on the pole and the arrangement of the bridle rings.

11-5. Terminating includes the completion of a proper drop wire run on the pole. Note that the drop wire is brought to the designated terminal through the bridle rings. That is, the wire runs first through the bridle rings highest on the pole and then through the rings above the proper wiring channel. To determine which wiring channel you should use, note the location of the lugs on which the wire will end. If you are facing the

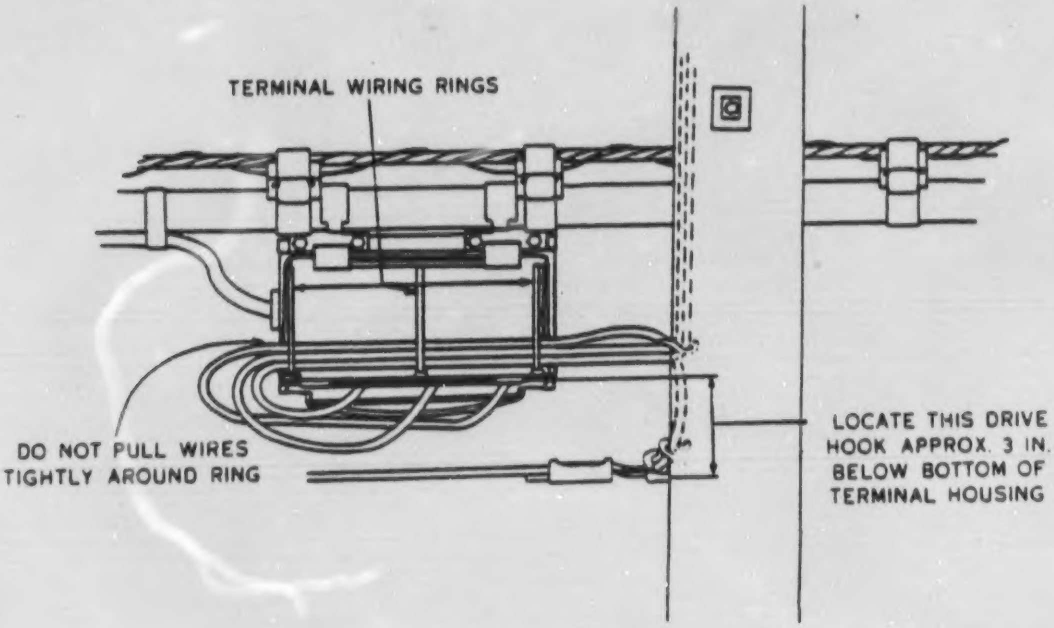
TERMINAL WIRING RINGS
DO NOT PULL WIRES TIGHTLY AROUND RING
LOCATE THIS DRIVE HOOK APPROX. 3 IN. BELOW BOTTOM OF TERMINAL HOUSING

Figure 105. Rear view of sheath-mounted terminal installation.

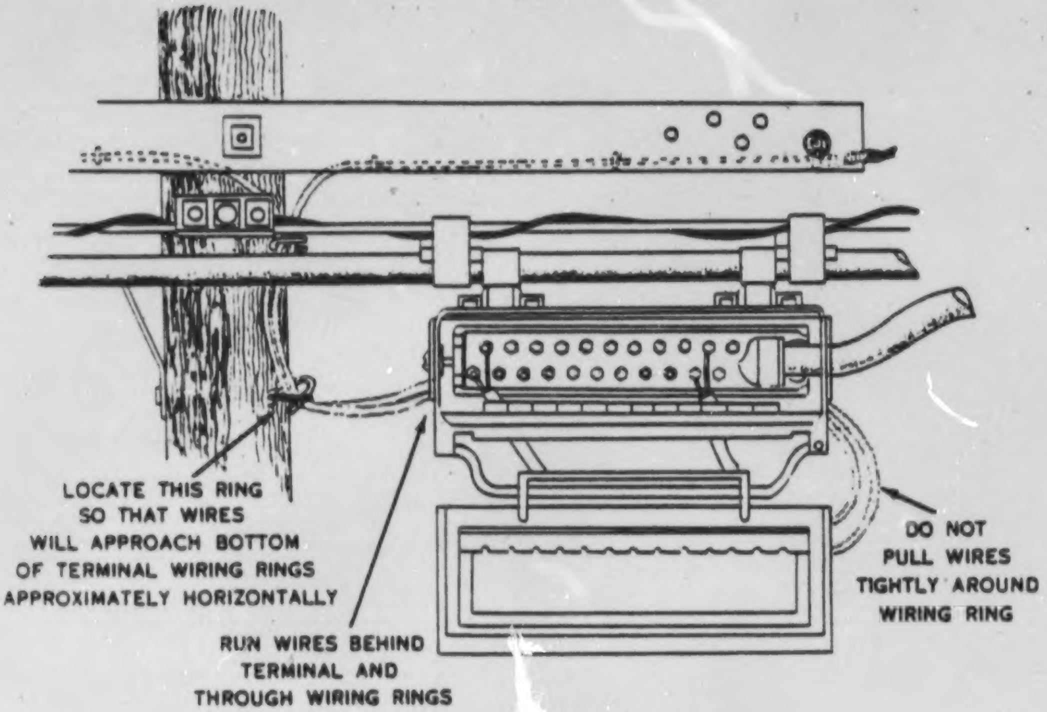
LOCATE THIS RING
SO THAT WIRES
WILL APPROACH BOTTOM
OF TERMINAL WIRING RINGS
APPROXIMATELY HORIZONTALLY
RUN WIRES BEHIND
TERMINAL AND
THROUGH WIRING RINGS
DO NOT
PULL WIRES
TIGHTLY AROUND
WIRING RING

Figure 106. Wire runs to sheath-mounted terminal at guardarm pole.

terminal and the binding posts for your drop are located near your left hand, bring the drop wire through the channel on your right. In other words, bring the wire through the side opposite the binding post to which it will be connected. Then thread the wire through all three of the bridle rings located below the terminal. By running the drop wire through the opposite channel, you leave extra wire so that if the wire is changed in the future, the installer can reach any pair of terminal binding posts by removing the wire from the lower bridle ring. The reconnected wire will then run from the channel to the two bridle rings and up the other channel to the terminal binding post.

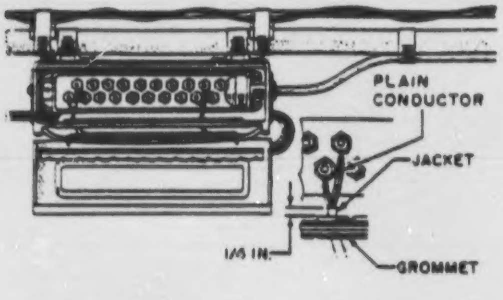
PLAIN
CONDUCTOR
JACKET
1/8 IN.
GROMMET

Figure 107. Wire connection at sheath-mounted terminal.

11-6. **Wire Run.** Remember that the wire run on the pole is made according to the requirements of good appearance and that each section of the wire run must be properly arranged. The bridle

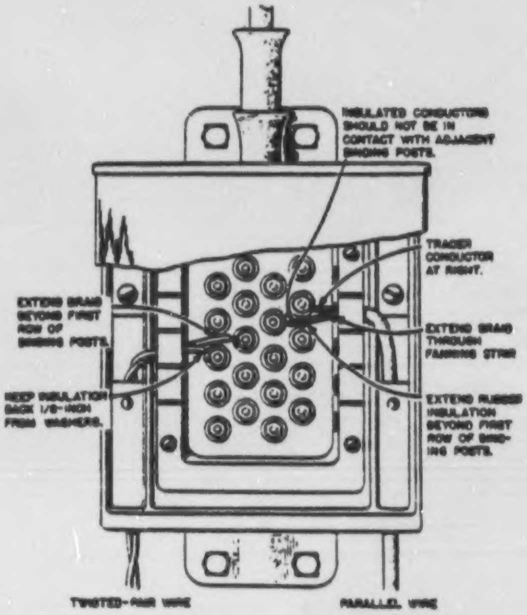
INSULATED CONDUCTORS
SHOULD NOT BE IN
CONTACT WITH ADJACENT
BINDING POSTS.
TRACER
CONDUCTOR
AT RIGHT.
EXTEND BRAID
BEYOND FIRST
ROW OF
BINDING POSTS.
EXTEND BRAID
THROUGH
FANNING STRIP
KEEP INSULATION
BACK 1/8-INCH
FROM WASHERS.
EXTEND RUBBER
INSULATION
BEYOND FIRST
ROW OF BIND-
ING POSTS.
TWISTED-PAIR WIRE
PARALLEL WIRE

Figure 108: Wire termination at pole-mounted terminal.

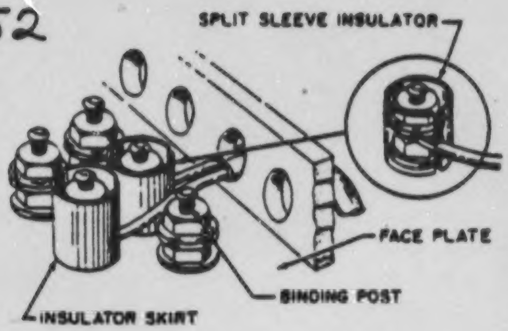

Figure 109. Use of binding post insulators.

ring locations are selected to insure sufficient wire clearance and neat vertical wire runs. In figure 104 note that the bridle ring spacing allows room for the terminal-can cover to be removed. Note also that the bridle rings are spaced according to the size of the terminal installed, because obviously more space is needed for large terminals than for small ones.

11-7. Wiring runs for sheath-mounted terminals are made to give uniformly neat appearance by grouping each run in a drive ring. (See figs. 103, 105, and 106.) This drive ring is so located that the wires running to the terminal will be in line with the terminal rings.

11-8. Terminating drop wiring on sheath-mounted terminals is a simple operation. First, obtain the proper length of wire and, second, puncture the grommet in the wire entrance hole immediately below the proper binding posts. Figure 107 shows the termination, including the grommet.

11-9. Again, you must follow good electrical procedures for terminating. Skin and clean the ends of the conductor. Loosen the upper nut and washer of the terminal lug and terminate the tracer conductor (ring) on the right-hand binding post. Terminate the plain conductor (tip) on the left-hand post. This maintains the polarity of the system. The first conductor is usually placed under the lower washer and around the binding post in the direction in which the nut is tightened. Leave approximately a ⅛-inch separation between the insulation and washer. (See fig. 108.) Tighten the nuts to give a firm contact and to prevent the wire from accidentally contacting the adjacent binding posts.

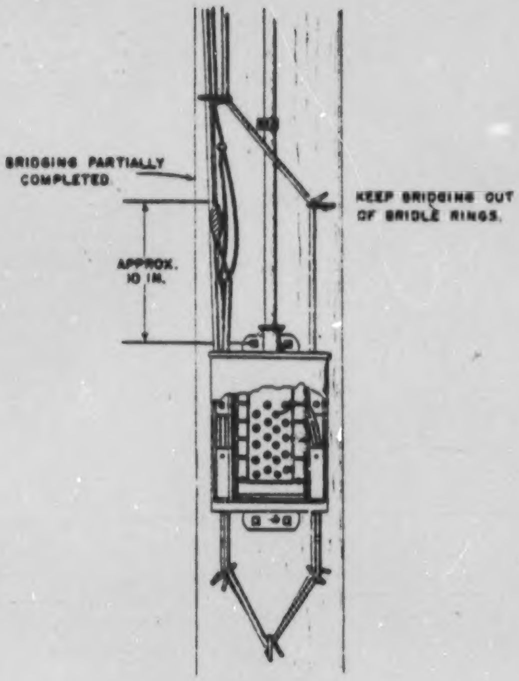
BRIDGING PARTIALLY COMPLETED
KEEP BRIDGING OUT OF BRIDLE RINGS.
APPROX. 10 IN.

Figure 111. Bridging three wires at a pole-mounted terminal.

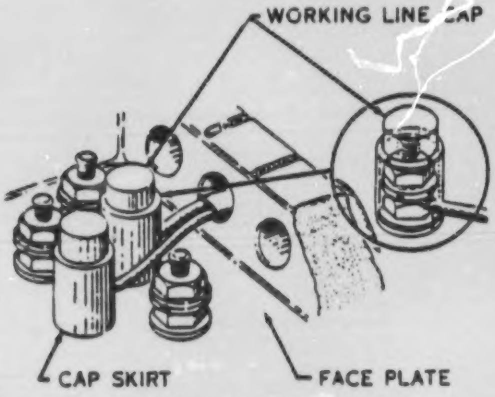

Figure 110. Use of cap binding post insulators.

11-10. After you have terminated the wires in the terminal, install binding post insulators on lines of relatively great importance to make sure that an accidental cross to another circuit is prevented. In commercial services these lines are picture transmission, teletypewriter, alarm, and remote control circuits. The insulators may be either the sleeve or the cap type. (See figs. 109 and 110.) Binding post insulators are available

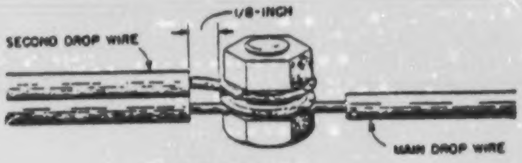

Figure 112. Use of 1–A type bridging connector.

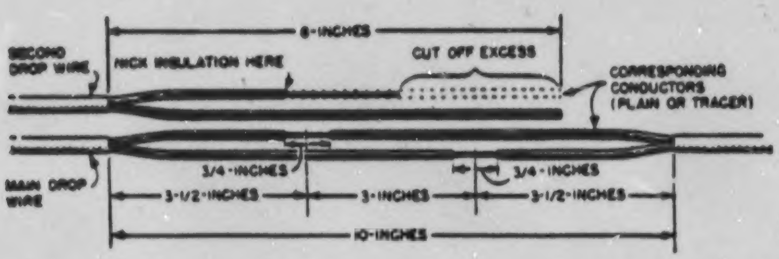
8-INCHES
SECOND DROP WIRE
NICK INSULATION HERE
CUT OFF EXCESS
CORRESPONDING CONDUCTORS (PLAIN OR TRACER)
3/4-INCHES
3/4-INCHES
MAIN DROP WIRE
3-1/2-INCHES
3-INCHES
3-1/2-INCHES
10-INCHES

Figure 113. Preparation of parallel drop wire.

in two sizes: No. 1 for ⅜-inch nuts on the ordinary binding post and 7–T fuses, and No. 2 for 7/16-inch nuts or 7–A fuses. Installation is simply a matter of slipping the insulator over the terminal. If the insulator does not fit securely, place a small piece of tape inside it.

11-11. Where party lines are involved or where several telephones are connected to the same cable pair, you must frequently connect three wires together. This connection, called bridging, is always necessary when three drop wires must be connected to the same cable pair. A connection of more than two wires on any post within the terminal-can is not advisable; therefore, the best procedure is to connect the third pair of wires outside the terminal box on the applicable drop wire. Figure 111 shows a partially completed bridge connection. Notice that the third drop wire is brought around the terminal box to the point of connection in the same manner as the regular drop wire runs.

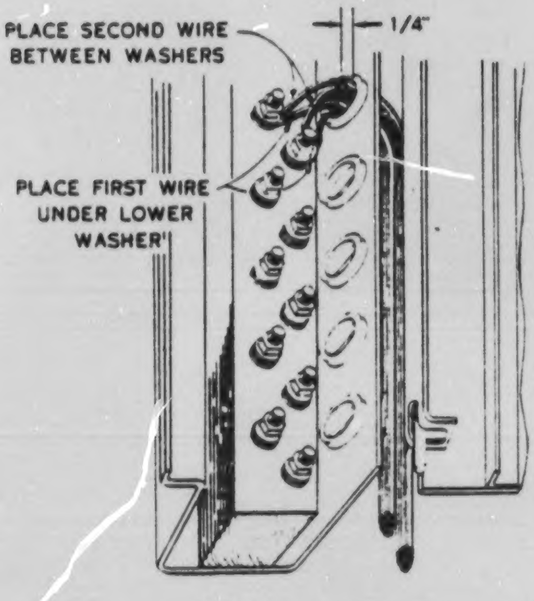
PLACE SECOND WIRE BETWEEN WASHERS
1/4"
PLACE FIRST WIRE UNDER LOWER WASHER

Figure 114. Bridging two wires at a sheath-mounted terminal.

11-12. Figure 112 shows the 1–A type bridging connector you should use, and figure 113 shows how the wire is prepared for the bridge. This detail is comparable to the work shown in figure 111. Remember, bridging connections may be insulated by wrapping them with rubber tape, over which you should place friction tape to give protection. The bridge location should not be within any bridle ring.

11-13. Bridging is frequently necessary at sheath-mounted terminals and is accomplished in a manner similar to that performed for pole-mounted terminals. Figure 114 shows two wires bridged to one pair of binding posts. Note that the outer covering of the drop wire extends at least ¼ inch inside the terminal. If three or four wires are to be bridged together, you must use a wire terminal, as shown in figure 115. Here we see the pair of bridle wires from the sheath-mounted terminal entering through the rubber grommet on the left and fastened to the two binding posts. Two parallel drop wires enter through the right grommet. One conductor from each pair is connected to the binding posts. The tight-fitting rubber grommets help protect the inside of the terminal from moisture.

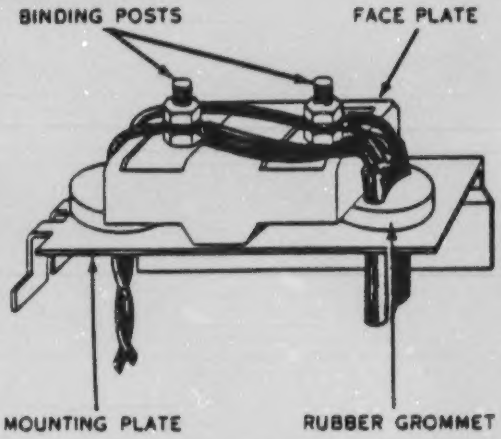
BINDING POSTS
FACE PLATE
MOUNTING PLATE
RUBBER GROMMET

Figure 115. Termination at a wire terminal.

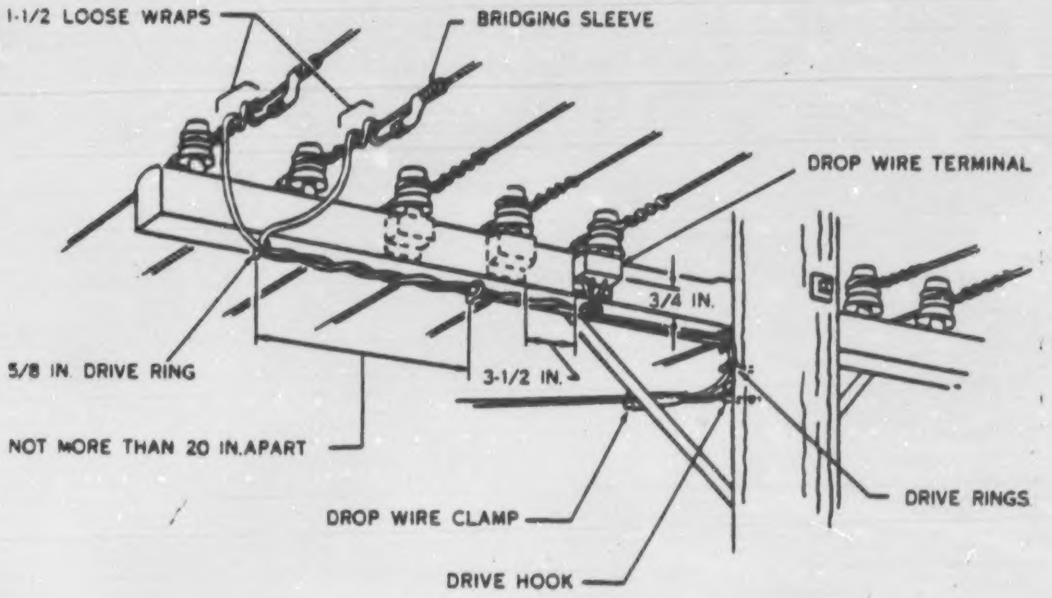
1-1/2 LOOSE WRAPS
BRIDGING SLEEVE
DROP WIRE TERMINAL
3/4 IN.
5/8 IN. DRIVE RING
3-1/2 IN.
NOT MORE THAN 20 IN. APART
DRIVE RINGS
DROP WIRE CLAMP
DRIVE HOOK

Figure 116. Drop wire termination at open wire pole with crossarm.

12. Open Wire Termination

12-1. Open wire is rarely, if ever, used for new installations. However, so much of this type of wire is already in service that it is a good bet that sooner or later you'll be called upon to terminate a drop or clear up a trouble condition at an open line termination. For these reasons, it is necessary for you to understand the principles of open wire termination. When terminations are to be made to open wire lines, the drop wires must be terminated at drop wire terminals. Bridle wire is then used for the connection between the drop wire terminals and the open wires.

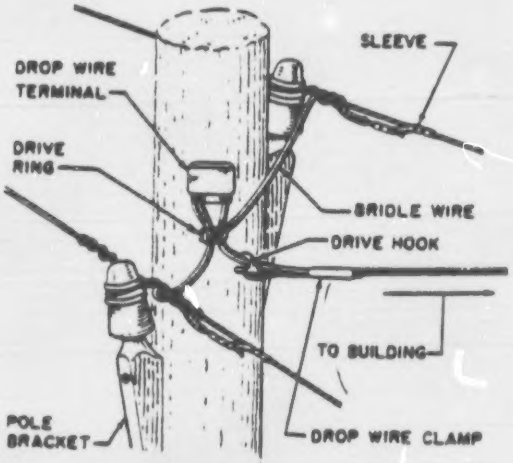
SLEEVE
DROP WIRE TERMINAL
DRIVE RING
BRIDLE WIRE
DRIVE HOOK
TO BUILDING
POLE BRACKET
DROP WIRE CLAMP

Figure 117. Drop wire termination at open wire pole without arms.

12-2. **Open Wire Terminal.** The drop wire terminal (fig. 115) consists of a faceplate, mounting base, and cover which hinges on the mounting base. Mounted on the faceplate are two binding

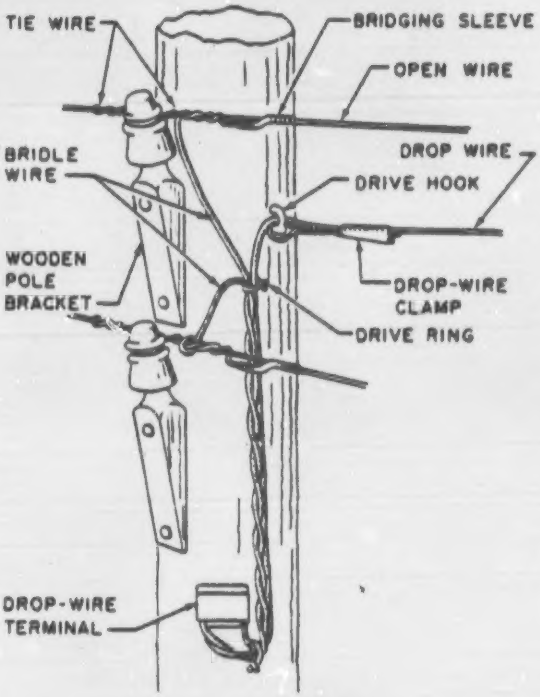
TIE WIRE
BRIDGING SLEEVE
OPEN WIRE
BRIDLE WIRE
DROP WIRE
DRIVE HOOK
WOODEN POLE BRACKET
DROP-WIRE CLAMP
DRIVE RING
DROP-WIRE TERMINAL

Figure 118. Termination where wires are on same side of pole.

posts, each equipped with a pair of washers and hexagonal nuts. The mounting base contains two mounting holes and two wire-entrance holes. The wire-entrance holes are equipped with rubber grommets, as shown in figure 115. One wire-entrance hole is used as the entrance for the drop wire, and the other as the entrance for the bridle wire. A maximum of two drop wires and one bridle wire may be terminated on the binding posts of a drop wire terminal.

12-3. Drop wire terminals should be located where they will be accessible and will not obstruct climbing space, although specific locations will vary with conditions at each installation. Whenever practicable, observe the following general rules:

(1) On poles with standard crossarms, locate drop wire terminals on the side of the crossarm, with the lower edge of the terminal ¾ inch above the bottom of the crossarm, as shown in figure 116. Locate the first drop wire terminal between the first and second wire from the pole. Additional terminals, when required, should be spaced 2½ inches apart on dead-end crossarms and 3½ inches apart on other crossarms.

(2) At dead-end crossarms, locate drop wire terminals on the side of the crossarm away from the dead-end brackets.

(3) On poles having pole brackets, locate the drop wire terminal between the pole brackets when the brackets are on opposite sides of the pole (fig. 117) and below the lower line wire when the brackets are on the same side of the pole (fig. 118).

12-4. **Terminal Installation.** Install a drop wire terminal with the binding posts pointing upward, as shown in figure 119. Attach the terminal to the crossarm or pole surface with two 1-inch No. 14 roundhead wood screws; then run the wiring as shown in figure 116.

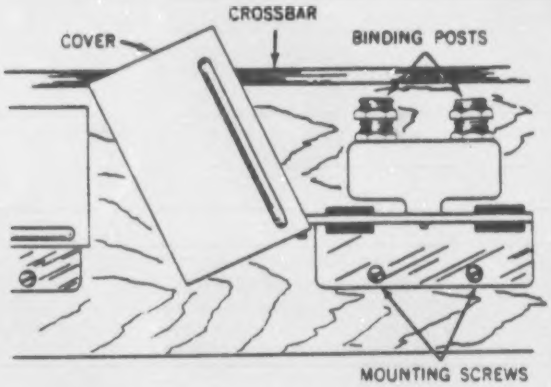

Figure 119. Mounting of drop wire terminal.

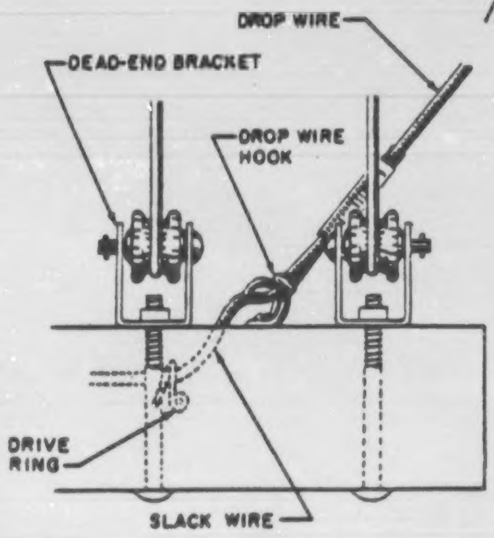

Figure 120. Use of drop wire hook on crossarm.

12-5. The attachments and the drop and bridle wiring are arranged as follows:

(1) When the drop wire is run to a drive hook on the pole, install one ⅝-inch drive ring close to the drive hook, and another ⅝-inch drive ring on the underside of the crossarm close to the pole. Install additional intermediate drive rings as required to limit the spacing between rings to approximately 20 inches.

(2) When the drop wire is run to a drop wire hook on the crossarm, install the first ⅝-inch drive ring on the underside of the crossarm below the drop wire hook. Note in figure 120 that the drive ring is not located immediately below the drop wire hook, but allows the drop wire to be run in a smooth curve from the hook.

(3) Install a ⅝-inch drive ring on the underside of the crossarm directly below the drop wire terminal.

(4) Install another ⅝-inch drive ring on the underside of the crossarm midway between the line wires on which the drop wire is to be terminated.

(5) Install additional intermediate drive rings on the underside of the crossarm as required to limit the spacing between rings to approximately 20 inches.

(6) Run the drop wire from the drive hook or drop wire hook through the drive rings to the drop wire terminal.

(7) Strip a sufficient length of neoprene jacket and rubber insulation from the end of the drop wire to permit terminating the conductors on the binding posts of the drop wire terminal. Leave enough of the neoprene jacket on the drop wire so that the jacket extends inside the terminal to

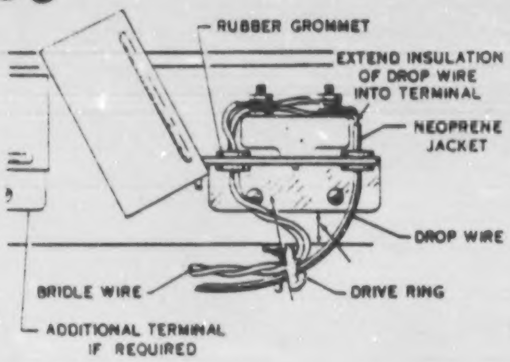
RUBBER GROMMET
EXTEND INSULATION OF DROP WIRE INTO TERMINAL
NEOPRENE JACKET
DROP WIRE
BRIDLE WIRE
DRIVE RING
ADDITIONAL TERMINAL IF REQUIRED

Figure 121. Wire connection at drop wire terminal.

a point where sunlight cannot reach the rubber insulation of the drop wire. Figure 121 illustrates a completed, crossarm-mounted, drop wire termination.

(8) Pass the drop wire through one of the wire-entrance holes in the drop wire terminal. Terminate the conductors of the drop wire under the lower washers of each binding post. If the wire-entrance hole does not have rubber grommets and if replacement grommets are not available, wrap enough ¾-inch friction tape around the drop wire to seal the entrance hole.

Note: If a second drop wire is to be bridged to the same pair of line wires, run the second wire through the same entrance hole and terminate its conductors between the two lower washers on each binding post. If three or four drop wires are to be bridged to the same pair of line wires, install another terminal for the additional wires.

(9) Select or cut a length of bridle wire long enough to run from the drop wire terminal to the line wires on which the termination is to be made.

(10) Strip enough of the neoprene jacket and rubber insulation from one end of the bridle wire to permit the conductors to be terminated on the binding posts at the drop wire terminal. Pass this end of the bridle wire through the second wire-entrance hole in the drop terminal and terminate the conductors between the two upper washers on each binding post. If necessary, seal the entrance hole, as discussed in step 8.

(11) Run the free end of the bridle wire through the drive rings to the line wires.

(12) Strip enough of the neoprene jacket and rubber insulation from the end of the bridle wire so that you can install a bridging sleeve on each conductor.

(13) Take 1½ loose wraps of each conductor around the line wire to which it will be terminated.

(14) Install each bridging sleeve on its corresponding line wire, as shown in figure 116. A bridging connector similar to the one shown in figure 122 may be used in place of a sleeve. A loop is formed from the stripped end of the bridle wire which is slipped around the bolt between the two flat washers. The bolt is then positioned over the line wire, as illustrated, before tightening the nut to make a secure connection.

12-6. As indicated at the beginning of this chapter, when all terminations have been completed, the installer checks his installation to insure that the installation and the line to which it is connected are free from defects.

13. Operational Testing

13-1. To insure that the subset installation will function properly, the installer-repairman must complete numerous tests at the time of installation. Even though central office personnel normally run a test on the assigned pair, the installer-repairman is often required to test the same pair from the terminal end before he completes termination. Also, after he completes termination, he must conduct a series of tests with the central office to find out if the newly completed installation is working properly. In case the equipment is not functioning properly, the installer-repairman should make the necessary adjustments or replacements to make certain that the new installation will give satisfactory service.

13-2. **Testing Before Termination.** Before the drop wire is terminated at the pole end, it is sometimes necessary to run a test of the assigned pair. This type of test is normally performed by connecting a telephone test set directly to the terminals of the assigned pair. If you can contact the central office in this manner and carry on a normal conversation, you can assume that you have good continuity between the terminals and

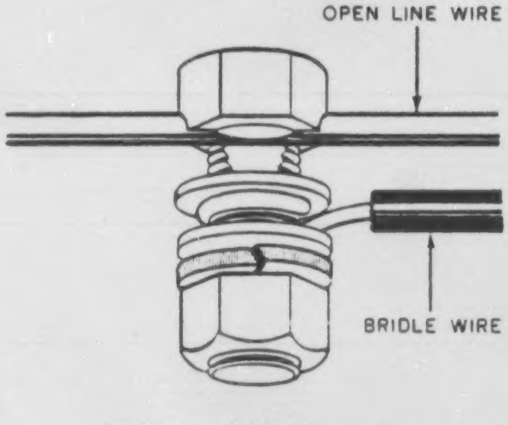

Figure 122. Bridging connector.

the central office. If you cannot contact the central office over the assigned pair, call in over a spare pair (if available) to advise the wire chief of the situation.

13-3. Another test which is sometimes performed, especially with open wire lines, is one used to identify the conductors. As you know, the ring conductor is the battery side of the line and supplies the electrical energy for the talking circuit. The tip conductor provides the return path for the current to the central office ground, thus completing the talking circuit. Also, the ring conductor is of negative polarity with respect to either the tip conductor or to ground. The test for identifying the conductors is made by connecting one lead of the test telephone to ground and the other test lead to first one conductor terminal and then the other. When the ring terminal is touched with the test lead, a loud click should be heard in the receiver of the test set. When the tip terminal is touched with the test lead, there should be either no click at all or a very slight click, depending on the difference in potential between the central office ground and the ground at the test location.

13-4. An additional check to verify that you have made proper identification of the ring conductor is to switch the test set to the TALK position and blow or whistle into the transmitter of the test set while it is connected between ground and the terminal which you have identified as ring. If you have properly identified the ring conductor, sidetone will be heard in the receiver of the test set, providing that you are receiving electrical energy for the talk circuit via the ring conductor. The absence of a loud click or sidetone on either side of the line indicates that a fault exists between the test point and the central office.

13-5. **Testing After Termination.** After the subset has been installed and all terminations have been completed, the newly installed station must be tested for proper operation. Normally, the installation is checked by the performance of ringing, transmission, reception, and noise tests. Also, with a dial telephone a check is made of the dial speed.

13-6. These operational tests are made by calling the installation wire chief or, in large installations, the test desk operator. In either case, a standard testing operation is completed after you have made an operational or preliminary check to the switchboard. The preliminary check not only proves that continuity has been established and that the telephone will operate but also gives you an opportunity to improve connections. Then the completion of the ringing, transmission, reception, and noise test with the wire chief will show detailed defects. Remember that a routine call will not accomplish this purpose. In addition to testing both sides of the line for grounds and for foreign voltage, the instruments will indicate whether or not the condenser in the ringing circuit of the telephone subset is properly connected and whether the subset dial is adjusted for the proper speed.

13-7. The tests performed with the wire chief are usually started by the installer calling in and reporting that he is ready for a test. The wire chief or the test desk operator then prepares for the test and calls the installer back. The ringing test is completed automatically when the wire chief calls back. The transmission test is completed by holding the handset in a normal manner and talking in a normal, conversational tone. For this purpose, hold the transmitter directly in front of your mouth so that your lips almost touch the mouthpiece. The reception test is completed when the words received are distinct and understandable. A satisfactory noise test is truly the absence of noise, because a scraping noise indicates that some portion of the installation is wrong. If you hear the scraping noise when no part of the telephone is being moved or when the transmitter is being blown into, the transmitter should be replaced. A scraping noise which changes in volume when the cords are shaken indicates that the cord should be tightened.

13-8. Remember that any trouble noticed at the time the test is completed should be found and corrected. Only minor troubles will probably be found at this time, because most installers can be expected to do workmanlike jobs on the installation. But after these are corrected, future troubles are entered for permanent information on the line record.

13-9. If your tests show the line and installation to be satisfactory, then you must complete the local Communications Service Order. You are required to confirm the cable pair and terminals used in terminating the station. You must list the apparatus used on the back of the installation work copy. This listing should show what material you installed that was new or used, what you did with it, and what was connected or changed. Any supplementary equipment installed should also be listed. After this has been done, the service order must be signed and turned in through the service foreman to the central office.

13-10. You should complete the chapter review exercises in the workbook before you proceed to Chapter 4, which covers selective ringing and extensions.

CHAPTER 4

Selective Ringing and Extensions

CONFIDENTIAL conversation was practically an impossibility with the old-time rural party line. To obtain the line for an emergency call, a person often had to break into the conversations of others. With all of its disadvantages, however, the party line served better than any printed publication for the distribution of local news and advertisements, and it is a time-honored means of providing a maximum of communication with a minimum of equipment. The principle is still good, even though the system and equipment have been modified for modern use.

2. With modern party lines, selective ringing systems are used which ring only the bell of the telephone for the party being called. Thus, the telephone of any one party on the line rings only when that particular party is called.

3. As an installer-repairman, you must have a knowledge of selective ringing systems to properly connect telephone subsets to a party line. Furthermore, to become proficient in the installation of telephone equipment, you must have a knowledge of extension ringers and telephones.

4. It is the purpose of this chapter to briefly discuss the connection of extension ringers and telephones, review telephone ringer operation, and explain some of the methods used in selective ringing.

14. Extension Ringers and Telephones

14-1. Greater benefits may be derived from a single incoming line by using an extension. This may be an extension of only the ringer portion of the telephone or of the entire telephone.

14-2. **Extension Ringers.** Extension ringers increase the utility of the telephone by increasing the area over which a telephone call can be announced. In a shop area a loud ringing bell is generally used for the extension ringer. (See fig. 123.) Various types of these bells are used—some operating on normal ringing current and others through a system of relays on alternating current at 110 volts. The bell selected for any particular installation is determined by the conditions of the area. Proper location of the bell, however, will insure maximum efficiency.

14-3. Connection, in most cases, is a matter of bridging the bell across the ringer of a subset or, if the bell is equipped with an internal condenser, of connecting the bell directly across the line. Remember when connecting extension ringers that a condenser must be included in the circuit by one of the two means mentioned. In any case, the extension ringer or bell must be connected in accordance with the instructions furnished with the unit.

14-4. As an installer, you must be familiar with the way ringer bells operate so that you can make any necessary adjustments. To better acquaint you with ringer bells and ringer systems, let us briefly review ringer operation. Having completed Chapter 5 in Volume 1 of this course, you know the operating principles and can recognize many of the bell features shown in figure 124. The ringer has two coils of wire, each wound on an iron core with an armature pivoted above one end of a permanent magnet. The creation of a magnetic field, which causes the armature to move from one pole to the other, operates the ringer. When an electric current is passed through the ringer windings, one end of the armature is pulled by the current (if the polarity is right) in the same direction as by the permanent magnet. Since unlike poles attract and like poles repel, the left end of the armature in figure 124 is attracted to coil C1 while the other end of the armature is repelled by C2. As a result, the clapper strikes G2. On the other half of the ac cycle, when the current through the coils is reversed, the polarity of the electromagnet is reversed and the armature is attracted in the opposite direction. This causes the clapper to strike G1, as shown in the illustration. Obviously, alternating current passing through the ringer windings causes the armature to vibrate with the current alternations. In actual practice, the current used with ordinary ringers has a frequency of 20 cycles per second.

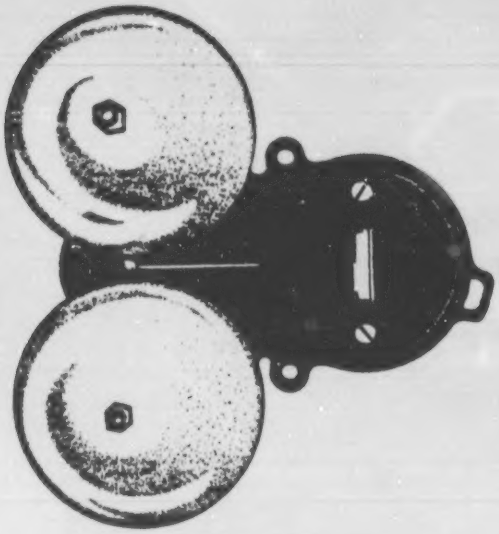

Figure 123. Loud ringing bell.

14-5. Note in figure 124 that the ringer has a biasing spring to regulate the movement of the armature. Although all biasing springs are not mounted in identical positions, they have the same purpose. When ac ringing current is used, the biasing spring prevents tapping of the bell when any current except ringing current flows through the set. By adjusting the tension of the biasing spring, you can stop such tapping and can also slightly change the sound of the bell. To repeat, the primary purpose of the biasing spring is to prevent bell tapping. While we are still thinking of ringers, it should be noted that some modern ringers use only one coil with two windings. The operating principles, however, are basically the same as those described in Volume 1 of this course.

14-6. If several people frequently use a subset, the addition of an extension subset may speed office or shop operations and increase the efficiency of the telephone. A typical installation might have two office telephones, one in an outer office and the other in an inner office.

14-7. **Extension Telephones.** Extension telephone installations are simple arrangements. Basically, we have two telephones connected in parallel so that they can operate from a single line. The two are joined to the line at the protector or through the use of a connection block, as discussed in Chapter 2.

14-8. Just as individual subsets may be installed with wiring through duct systems, so can a flexible arrangement be made for extension telephones; however, this arrangement is practical only for permanent wiring. The flexibility is attained by providing telephone outlets at selected locations; thus, you can attach the subset to any outlet. Frequently, a standard three-prong plug which insures correct polarity is used for such attachment; at other times, a permanent connection is made at an established outlet.

14-9. The various duct systems and conduit arrangements were also discussed in Chapter 2. Remember? In general, the system consists of a gridwork of ducts connected to distributing terminal cabinets, where the ducts are laid in parallel branches with junction boxes at the intersection of cross ducts. Since floor outlets generally occur every 24 inches along each branch, a variety of telephone arrangements can be selected. By comparison, a conduit system consists of a network of iron conduits extending from the terminal distribution cabinet or from a supply closet. These conduit runs may end at walls or columns in the building. Outlets in the floor can also be used, but the conduit arrangement is better suited for wall outlets than the floor outlets.

14-10. Sometimes a telephone line can be arranged for the use of several parties. Then the term "selective ringing" is used to indicate any one of several methods by which an individual ringer is operated without disturbing the other parties.

15. Selective Ringing Methods

The use of the multiple service line is indicated by the necessity for saving materials and for offering a maximum amount of service at a minimum cost. By installing several telephones on the same line, additional service may be given without expanding the existing facilities. The telephones in this system, however, are not extensions; they are distinguished from extension telephones by the fact that each is located to serve a separate party rather than to give ad-

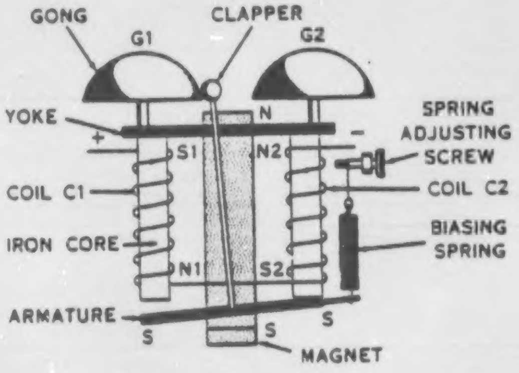

Figure 124. Ringer construction.

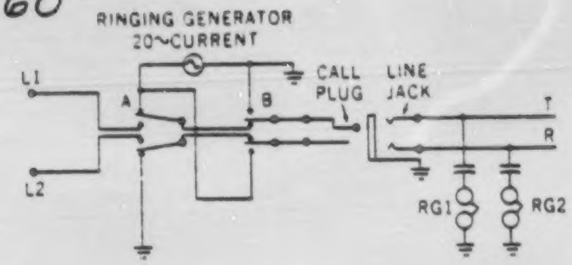

Figure 125. Ringing-to-ground circuit.

ditional facilities to the same party and that each is given a separate listing in the directory.

15-2. A multiple service line is called a multi-party line—in common usage, a party line. As previously stated, party lines may be used in areas where the number of telephone subscribers is increased beyond the switchboard capacity. In the Air Force or other service installations, a major saving in material may result from the use of party lines.

15-3. A party line, however, has disadvantages for the telephone user. The telephone is less available, because he may have to wait until another party has finished a call. Also the telephone user may be disturbed by continual ringing if code ringing (a distinctive series of rings for each telephone) is used to signal each party. Or the user may pick up the receiver and listen to another person's call.

15-4. Party lines have improved as a result of continued efforts toward reducing or eliminating their disadvantages. Some of these efforts, such as the lockout system used by some commercial companies, are very elaborate and are not necessarily important to the Air Force installer. The easiest way of improving party line service is to limit the number of telephone users on the line. In rural systems, as many as ten users may be found on a party line, whereas city party lines seldom have more than four users. Although two-party and four-party lines are used extensively, two-party lines are more common in the Armed Forces.

15-5. Greater privacy can be attained by using ringing methods, known as selective ringing, which signal only the party being called. Remember, however, that selective ringing differs from code ringing, which is heard by all parties on the line. With selective ringing the telephone user hears one ring only—his own. The selective ringing signal sounds like the one on a single-party telephone line, but the ringing circuit or the ringing signal is different for each party. The substation connections made by the installer determine the subset ringing arrangement.

15-6. The methods by which selective ringing is brought about are: ringing to ground, pulsating ringing, and frequency ringing. Of these, the one that does not require additional equipment and that is used by the Air Force is ringing to ground.

15-7. **Ringing to Ground.** Basically, the ringing-to-ground system consists of a few simple connections, which set up a separate ringing circuit for each of the parties involved. Furthermore, this principle applies on two-party lines or, with additional equipment, on four-party lines. When the connection is completed, the ground is used as a common conductor for the ringers. It forms a third conductor for the telephone line, but it is in use only while the party is being signalled.

15-8. Figure 125 shows a schematic diagram in which each party ringer is connected to only one side of the line; ringing power is connected to one side of the line at a time. It shows that 20-cycle ringing power at the switchboard is connected between ground and two ringing keys. When the plug is inserted in the jack (shown at the center of the illustration), operation of either the A or B part of the key will complete the ringing circuit desired; that is, one set of contacts (A) connects the tip (T) conductor ringing

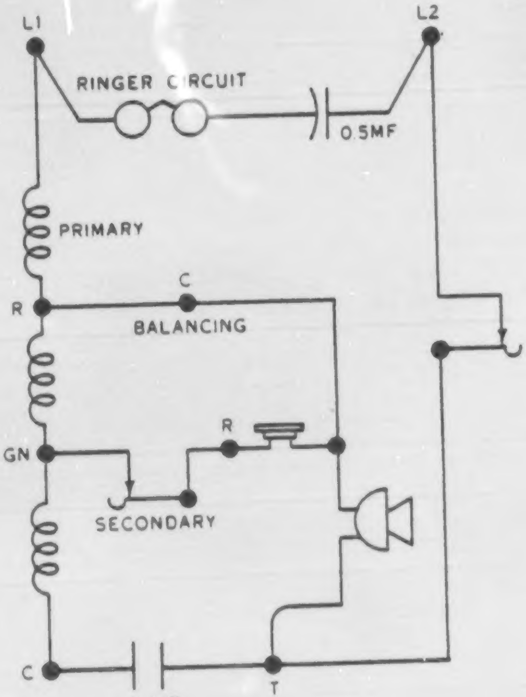

Figure 126. Simplified diagram of WECO No. 302 telephone.

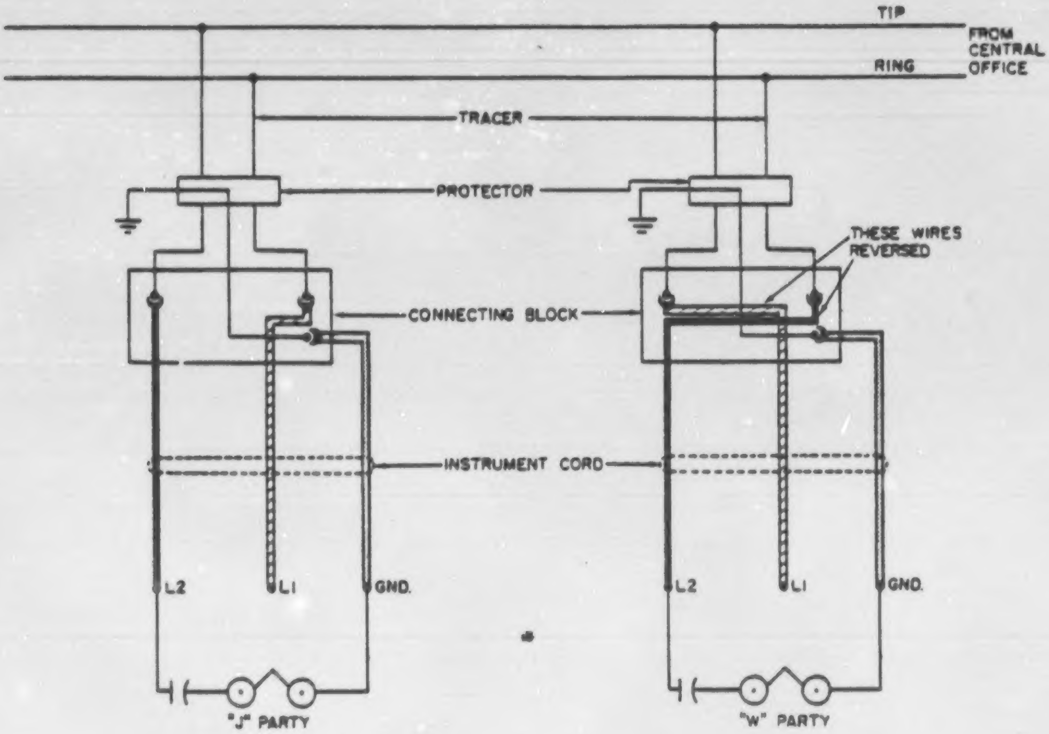

Figure 127. Connections for selective ringing-to-ground method.

circuit and the other set (B) the ring (R) conductor ringing circuit. Since both ends of the circuit thus established are firmly grounded, ringing power will operate the ringer (RG1 or RG2) to signal the desired party.

15-9. On switchboards used by the Air Force no new connections are necessary for grounded ringing circuits. The switchboard is normally grounded upon installation, and the larger switchboards are each equipped with a master ring (MR) key by which the ringing current is placed on the tip-to-ground or ringing-to-ground circuit. By referring to figure 125, you can see that the ringing current travels from the ring side of the line to the ground through that ringer which is connected by the B portion of the MR key. And so the ringer, which is connected to the tip side of the line, will not ring because both sides of that circuit will be at ground potential. This ringer can then function when the MR key is operated to place the ring side of the line at ground potential. On the same system a telephone which has its ringer connected in the normal manner (across tip and ring) will ring when the master ring key is in either position. L_1 and L_2 represents the calling party line.

15-10. In order to meet the requirements for two-party selective ringing, a three-conductor inside wire is run from the protector to the connecting block, where a three-conductor cord is then used for the telephone connection. The third conductor in each case forms part of the continuous ground wire from the protector ground to the telephone ground terminal. This ground can then be completed by a slight change in the internal connection of the subset. Figure 126, a simplified diagram for the WECO 302 subset, shows the arrangement of wiring and connections. As you will recall, this is a common battery TP–6.

15-11. In the telephone circuit diagram, you see that the ringer is connected in series with a condenser and both the ringer and condenser are located between the L_1 and L_2 terminals of the subset. This condenser, which blocks battery current from the ringer, is necessary for the operation of the system. When connections are made for selective ringing, the condenser must be kept in the ringer circuit. The installer must remember that various telephone manufacturers have distinct differences in their telephone instrument circuits and that although the principles given here apply to them all, the specific wires or terminals moved must be determined from the wiring diagram for the particular subset.

15-12. In figure 126 note that a wire is con-

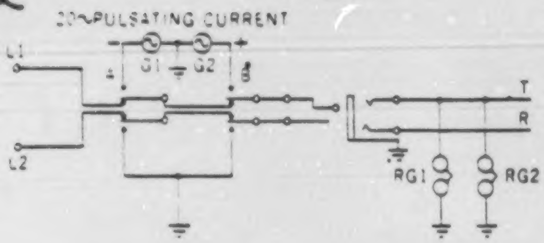

Figure 128. Ringing circuit for two-party ringing to ground.

nected from the ringer to the L_1 terminal. To connect the telephone ringer to ground, you have only to disconnect the ringer wire from the L_1 terminal and reconnect it to the telephone ground terminal. The circuit, after reconnection, is shown by figure 127. Most telephones now in service are already wired this way when they are shipped from the factory. All wiring changes required for a particular ringing arrangement are made at the connecting block.

15-13. Figure 127 also gives additional information on the selective ringing-to-ground system. For example, there are two parties—J and W. As illustrated by the diagram, the J-party rings from the tip side of the line and the W-party from the ring side.

15-14. When making the connections for selective ringing, you should remember that identical procedures are used for both sides of the lines except for an additional step for the W-party. To connect W-party, first complete the ground connection, if required, then reverse the L_1 and L_2 wires at the connecting block.

15-15. **Pulsating Ringing.** To ring more parties with the ringing-to-ground method, commercial telephone systems sometimes use pulsating ringing equipment. This type of ringing is feasible with two-, three-, or four-party lines; however, it requires the use of additional equipment in both the subset and the central office. At the central office, dc generators are used to generate pulsating ringing current. These generators are connected so that either positive or negative pulses can be applied to the lines for ringing purposes. At the subset installation, each telephone is equipped with a biased ringer and, in the case of a three- or four-party line, a relay or a cold-cathode, gas-filled tube. When positive pulses are applied to one line, only one of the two ringers operate. Reversing the pulses causes the second ringer to respond. The same is true for the other side of the line. Thus, four ringers can be selectively operated.

15-16. *Biased ringer.* Figure 124 can also represent a biased ringer used with a pulsating dc generator. When current is applied as shown, the bottom end of coil C1 becomes magnetized to attract the armature, while at the same time, coil C2 repels the armature. At the peak of the pulse, the combined action is strong enough to overcome the effect of the spring, and the clapper

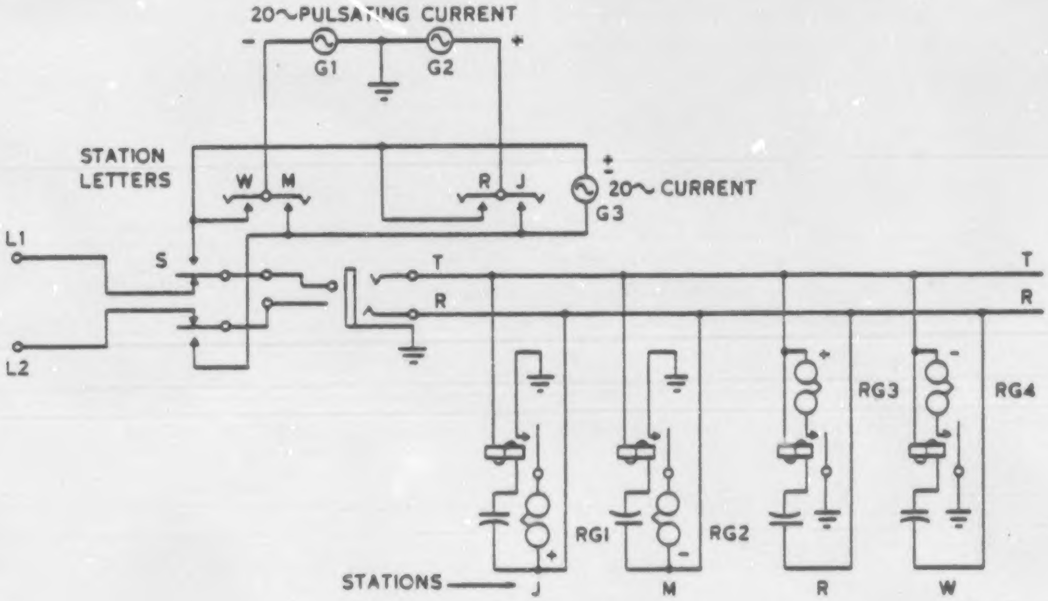

Figure 129. Four-party ringing using ac relays.

strikes G2. At the end of the pulse, the spring pulls the armature back to the position shown, and the clapper strikes G1. This action is repeated for each pulse of dc.

15-17. If pulsating current is passed through the coils of the ringer in the opposite direction, the iron cores of C1 and C2 are magnetized with polarities opposite to those shown in figure 124. C2 now attracts the armature. However, because of the action of the biasing spring, the armature is already positioned to C2 and no movement of the armature is possible. At the end of the pulse, the armature is still held motionless by the action of the spring, and the ringer does not ring. If two telephones are each equipped with a ringer which is biased in opposite directions, a pulsating current in one direction will operate one ringer, and a pulsating current in the opposite direction will operate the other. Therefore, if some means for changing the direction of the ringing current is provided, the ringers will operate independently of each other, providing a means of two-party selective ringing.

15-18. *Two-party ringing.* Figure 128 illustrates a two-party ringing system using pulsating dc. When switch A is operated, the calling line is disconnected and generator G1 applies negative pulses to the tip of the called line. The pulses pass through ringers RG1 and RG2 and back to G1 through ground. However, only one ringer responds, as the other one is reverse biased and cannot ring. To signal the other subscriber, the B switch is used. This connects generator G2 to the circuit, and positive pulses are now applied to the calling line. With the polarity of the ringing current reversed, the ringer at the second telephone responds while the first one remains silent.

15-19. *Four-party ringing.* Four-party ringing is possible through the use of some additional components. Each substation requires an ac relay in addition to the biased ringer, as shown in figure 129. As you can see, the central equipment includes an ac generator as well as the two dc pulsating generators.

15-20. When switch S is held in the operated position, the 20-cycle ac generator is applied across tip and ring to operate the ac relays at the four substations, closing the ringer circuits to ground. With switch S held operated, let us also operate switch W. With G1 connected to the circuit, negative pulses on the tip lead cause RG4 to operate. In a like manner, closing switch J applies the positive pulses from G2 to the ring lead of the circuit, causing RG1 to ring. Operating switch M or R has a similar effect on RG2 or RG3.

15-21. Figure 130 illustrates another method of providing four-party selective ringing. This system is similar to the one shown in figure 129. However, if you check figure 130, you will see that we have eliminated the 20-cycle ac generator at the central office and the ac relays at the substations by using cold-cathode, gas-filled

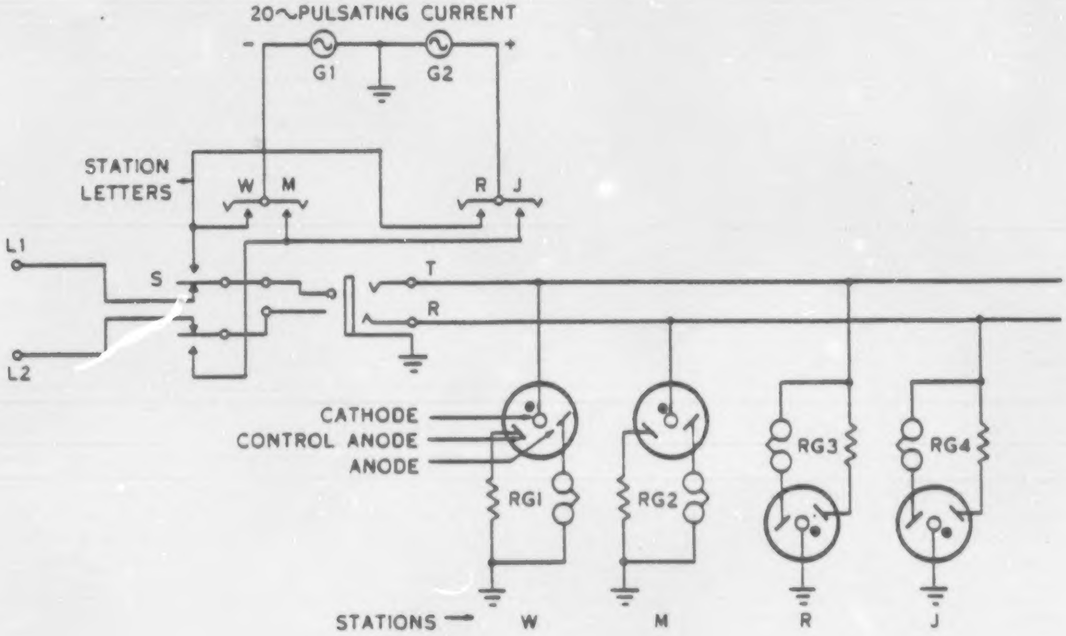

Figure 130. Four-party ringing using gas-filled tubes.

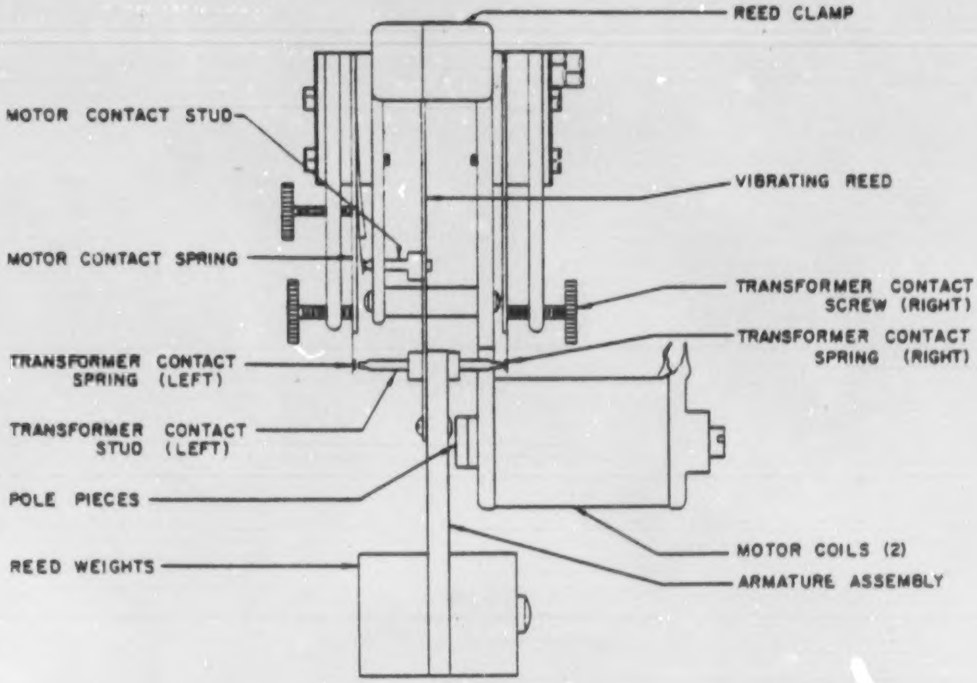
REED CLAMP
MOTOR CONTACT STUD
VIBRATING REED
MOTOR CONTACT SPRING
TRANSFORMER CONTACT SCREW (RIGHT)
TRANSFORMER CONTACT SPRING (RIGHT)
TRANSFORMER CONTACT SPRING (LEFT)
TRANSFORMER CONTACT STUD (LEFT)
POLE PIECES
MOTOR COILS (2)
REED WEIGHTS
ARMATURE ASSEMBLY

Figure 131. Frequency generator.

tubes. The arrangement of the master switch, the four station switches, and the two pulsating dc current generators is identical in both illustrations.

15-22. Before discussing the operation of the system shown in figure 130, we must first understand the operation of the cold-cathode tube. The tube contains three elements and is filled with an inert gas such as neon or argon. The three elements are called the cathode, the control anode, and the anode, as shown in figure 130. When the proper voltage is applied between the cathode and the control anode with the cathode negative, the gas in the tube is ionized, and this causes electron flow between cathode and anode as long as the anode is positive in respect to the cathode.

15-23. With this brief explanation in mind, let's turn to figure 130 and see how this simple system works. Operating switch 3 and switch W applies the negative from G1 to the tip lead of the party line. Only station W responds, as the polarity is reversed at station R. Current across the tube operates RG1 and returns through ground to G1. When switch S and switch R are operated, positive battery from G2 is applied to the tip of the line and now RG3 rings. Switch M and switch J have similar effects on RG2 and RG4 through the ring lead of the party line.

15-24. **Frequency Ringing.** A third method of providing four-party selective ringing is called harmonic, or frequency, ringing. This system requires ringers and generators of a different design from those previously discussed. The armature-clapper of the relay is a spring reed made to vibrate only when current of a specific frequency is applied to the coils. The frequency is set at the factory by the positioning of a weight on the reed. This is different for each of the four stations on the party line. At the central office, frequency generators of a design similar to that shown in figure 131 may be used. Each frequency requires an individual generator. The amount of weight attached to the armature controls the frequency of the vibrating reed. Movement of the armature to the motor coils opens the motor contacts, deenergizing the coils. This, then, allows the armature to swing back to close the contacts again. At the same time, the two sets of transformer contacts are alternately closing and opening, applying reversing current in the primary winding of the generator transformer. Through the secondary winding an ac ringing current of a specific frequency is applied to the line.

15-25. In this system, all four ringers are connected directly across the line, between tip and ring. As a result, each time ringing current is applied, regardless of the frequency used, all of the ringers receive ringing current. However, only that ringer which is designed to respond to the particular frequency will ring each time; the others remain silent. The selection of the particular frequency and its application to the line is controlled by the same switches as previously described.

15-26. The most commonly used frequencies are 162/3, 331/3, 50, and 662/3 in one type of generator, or in another type, 30, 42, 54, and 66 cycles. As there are numerous systems in use, if you should become involved in the installation of a selective ringing system, follow the instructions furnished for the system concerned.

15-27. While our discussion of telephone extensions and ringer systems has been brief, it is of sufficient depth to give you an insight into methods used by both Air Force and commercial installations. Complete the review exercises in the workbook before you turn to the final chapter of the volume, where we shall discuss troubleshooting procedures used by the telephone installer.

CHAPTER 5

Station Trouble Isolation

IN VOLUME 2 of this course, we discussed the maintenance, troubleshooting, and repair of telephone subsets. The telephone subset, however, is not the only place in the system where trouble may develop. For example, if a telephone subset is in perfect operating order but fails to operate in the system, then the trouble is somewhere in the station wiring, the telephone cable or line, or in the central office. As an installer-repairman, you are responsible for the location of such troubles in the subset area. Also, you must cooperate with other telephone personnel to locate troubles in the lines, cables, or central office. The principles and procedures which the repairman follows in isolating these troubles are similar to those explained in Volume 2. Also, the test sets used for locating troubles in station and drop wiring are the same as those used in testing subsets. Although new details of finding trouble are included in this chapter, generally the methods of trouble location in the subset and trouble isolation in the station wiring are similar. It is the purpose of this chapter to discuss trouble isolation from the central office, trouble location in the subset area, and the elimination of such troubles.

16. Trouble Isolation from the Central Office

16-1. When trouble develops in telephone circuits, the central office is immediately affected. And so the problem is the responsibility of the wire chief, who must determine if the trouble is in the central office or in the circuit to the substation and must assign a repairman to correct the trouble wherever it may be.

16-2. **Location.** In general, the three possible trouble locations are, as shown by figure 132, in the central office, on the line, or in the substation. Although troubles at the various points are not identical, they are mostly common electrical faults such as opens, crosses, shorts, and grounds. The proper methods of isolation are determined after the faults have been traced to their probable locations.

16-3. The wire chief, who operates test sets from the central office, selects the sets to use and considers the basic troubleshooting factors: (1) the type of service, whether dial or manual; (2) the type of apparatus, according to the line and substation characteristics; (3) the weather conditions at the time the trouble was reported; and (4) the history of the equipment, which may provide a clue to the present trouble.

16-4. The wire chief not only must have the basic know-how but also must complete various tests from the central office. One of these, a telephone transmission test, tests the condition of the substation transmitter and receiver, provided the substation is not completely out of order.

16-5. **Tests.** Once the wire chief has determined that the trouble is not within the substation or the central office, he may choose any of several instruments for testing the substation line, his choice depending upon the equipment and size of the central office. In a large central office, a test desk may be available. (See fig. 133.) This single-position test cabinet is equipped to test dial or manual telephone station lines (both inside and outside the central office), outside plant wiring, and dial telephone substation equipment. The desk contains a volt-ohm-milliammeter, a dial speed indicator, a Wheat-

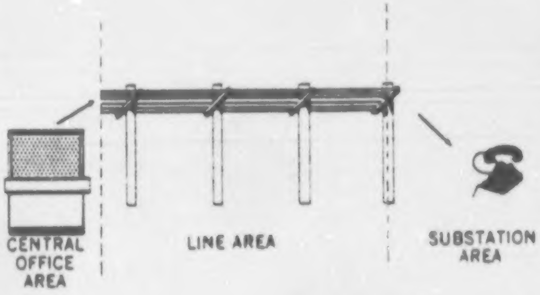

Figure 132. Trouble locations.

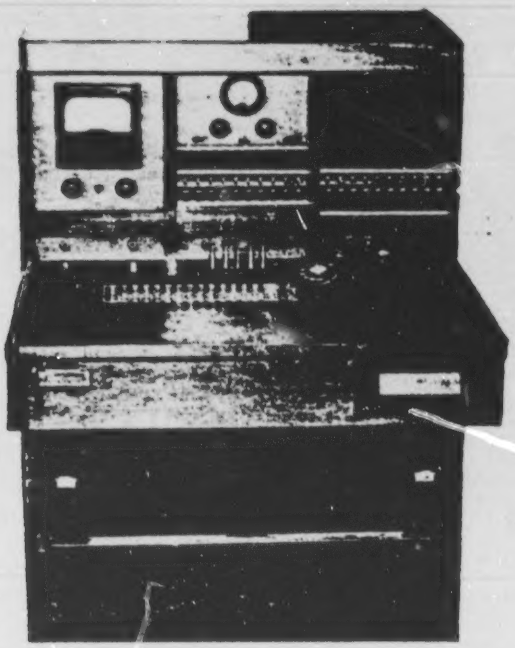

Figure 133. Type No. 1 test desk.

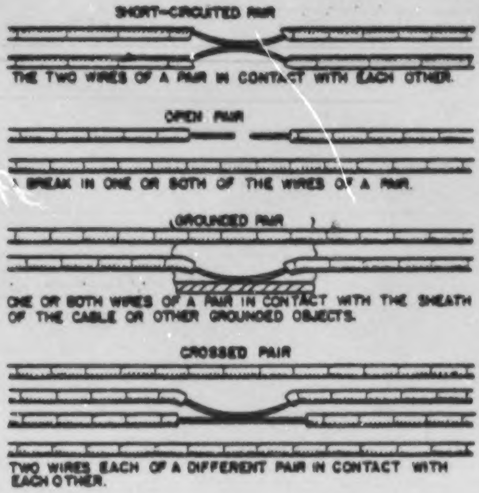
SHORT-CIRCUITED PAIR
THE TWO WIRES OF A PAIR IN CONTACT WITH EACH OTHER.
OPEN PAIR
A BREAK IN ONE OR BOTH OF THE WIRES OF A PAIR.
GROUNDED PAIR
ONE OR BOTH WIRES OF A PAIR IN CONTACT WITH THE SHEATH OF THE CABLE OR OTHER GROUNDED OBJECTS.
CROSSED PAIR
TWO WIRES EACH OF A DIFFERENT PAIR IN CONTACT WITH EACH OTHER.

Figure 134. Substation trouble causes.

stone bridge, dry-cell test batteries, and various test trunk circuit apparatus and controls.

16-6. The test desk is operated by two rows of lever switches on the switch shelf and five push switches, which are associated with the out-call wires and are located at the left of the lever switches. Remember, operating a test desk is complicated and requires an experienced man;

TABLE 2

POSSIBLE TESTS FROM TEST DESK

Volt-Ohm-Milliammeter

1. Loop circuit tests, transmission test, and insulation breakdown test.
2. Ground on ring (—) side of the line.
3. Ground on tip (+) side of the line.
4. Loop resistance.
5. Insulation leakage.
6. Negative potential on the ring (—) side of the line.
7. Positive potential on the ring (—) side of the line.
8. Negative potential on the tip (+) side of the line.
9. Positive potential on the tip (+) side of the line.
10. Checking the voltage of the test batteries.
11. Transmission test.
12. Line equipment bridge test.
13. Capacitance of station ringer capacitors.

Ringing and Miscellaneous Tests

1. Ringing on bridged single-party line.
2. Loop resistance tests and fault-locating measurements.

Auxiliary Test Cord Circuit Tests

1. Ringing over individual or two-party lines.
2. Dial speed and pulse ratio (percent make) tests on dial station lines.
3. Sounder and tone tests on lines to identify cable pairs.
4. To connect the howler to station lines.

Sounder Cord Circuit Tests

1. Identifying pairs or conductors in the cable by short-circuiting or grounding the conductors.
2. Identifying pairs or conductors in a cable by connecting a receiver across the conductor.
3. Identifying pairs or conductors in a cable by opening the circuits or removing ground.

Wheatstone Bridge Tests

1. Loop resistance test.
2. Measuring the distance to a ground on a line by the resistance method.
3. Measuring the distances to a fault on a line by the two-wire Varley loop method.
4. Measuring the distance to a fault on a line by the Murray loop method.
5. Locating a fault on a line by the three-Varley method, using three wires.
6. Any other desired Wheatstone bridge tests requiring two or three wires.

TABLE 3
COMMON CAUSES OF WIRE TROUBLES

Causes of Opens

1. Wiring broken by excessive bending or twisting when the wire is placed.
2. Bullets piercing a wire.
3. Kinks and nicks in the wire, causing the conductors to break.
4. Poor splices pulling out under tension.
5. Inside wiring nails driven too far into the insulation, breaking the conductors.
6. Loose or dirty connections and lugs.
7. Blown, broken, or badly warped fuses.
8. Defects in the manufacture of the wire.
9. Excessive strain on the wire at the terminals, causing conductors to become loose.
10. Sharp or heavy objects striking a wire, causing a break.

Causes of Shorts

1. A drop wire swinging against an object, wearing off the insulation, and causing the two conductors to make contact. (This is called a swinging short.)
2. A break in the insulation of a drop wire at the drop clamp, with the clamp serving as the connector between the two conductors.
3. Water settling on an old deteriorated drop wire and acting as a conductor. (This is called a wet short.)
4. Dirty face plates on terminal cans serving as a conductor between the two lugs assigned to a pair.
5. Wiring at any point of termination extending too far and contacting another lug.
6. Inside wiring nails driven through the insulation so that the metal nailhead causes contact to be made between the two conductors.

Causes of Grounds

1. Bare conductors of a worn drop wire making contact with any grounded metallic object.
2. Wet or worn inside wiring making contact with grounded metallic object.
3. A broken bridge at the terminal can making contact with the terminal, cable stub, etc.

therefore, the wire chief or test deskman may be the only person who handles this job. Table 2 summarizes the tests which can be made from the test desk. The Varley and Murray loop methods are similar to the bridge test methods discussed in Volume 2 of this course.

16-7. When trouble is reported, the wire chief or test desk operator will normally perform a series of tests, such as those listed in table 2. From the results of these tests, the test desk operator can usually determine the approximate location of the trouble. If it appears that the trouble is in the subset area, the installer-repairman is dispatched to the scene. If it appears that the trouble is in a line or cable, the line and cable personnel get into the action. In some cases when the trouble is in a line or cable pair, the installer may be sent out to change the termination of a subset over to a good pair. When the trouble is in the subset area, the installer must run a series of tests to determine its exact location. After the trouble has been located, it must then be corrected.

17. Trouble Location Procedures

17-1. In locating faults in the drop, block, and station wiring, you can save much time and effort by careful analysis and systematic procedure. In some instances you can readily detect the probable location of a fault by a visual inspection of the line.

17-2. **Trouble Analysis.** Before proceeding to the station, have the test deskman give you information on the probable nature of the fault and

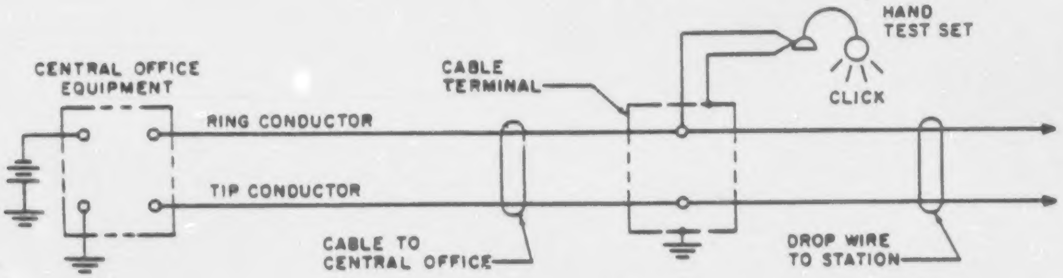

Figure 135. Use of hand test set for wire identification.

the cable pair, and terminal numbers associated with the faulty circuit. Then go directly to the vicinity from which trouble was reported and make a visual inspection for obvious breaks, damaged insulation, and proper terminal connection.

17-3. The common causes of wire trouble are opens, shorts, crosses, or grounds, as shown in figure 134; and they, in turn, result from such obvious causes as those tabulated in table 3.

17-4. Remember that the line conductors in a telephone circuit are classified as the tip and the ring conductors. The ring conductor, or negative side of the line, supplies the electrical energy for the talking circuit; the tip conductor provides the return path for the current to the central office ground, thereby completing the talking circuit. When testing circuits and locating faults, you will frequently have to identify the tip and the ring conductors.

17-5. Although the procedure for identifying conductors was mentioned earlier in this volume, a more complete explanation of how this is done with a hand test set is given in the following paragraphs. Refer to figure 135, which shows the test set connected at the cable terminal, while reading the following steps:

(1) Select a convenient test point, such as a cable terminal, connecting block, or station protector, where a suitable electrical ground is available.

(2) Clip one lead of the test set to the ground.

(3) Touch the other lead of the test set alternately to the two terminals at the test location. As each terminal is touched, you should hear a click in the receiver of the test set. The click on the ring (battery) side will be distinct and clearly audible, whereas the click on the tip side will be faint and may not actually be heard, depending on the difference in potential between the central office ground and the ground at the test location. The absence of a loud click or sidetone on either side of the line is an indication that a fault exists between the test point and the central office.

(4) Place the test set switch in the TALK position.

(5) Check for proper identification of the ring conductor by blowing or whistling in the transmitter of the hand set while the test set lead is touched or connected to the ring side of the line. If the identification is correct, you will hear sidetone in the receiver of the hand set.

17-6. **Types of Line Faults.** As mentioned before, there are four types of common line faults:

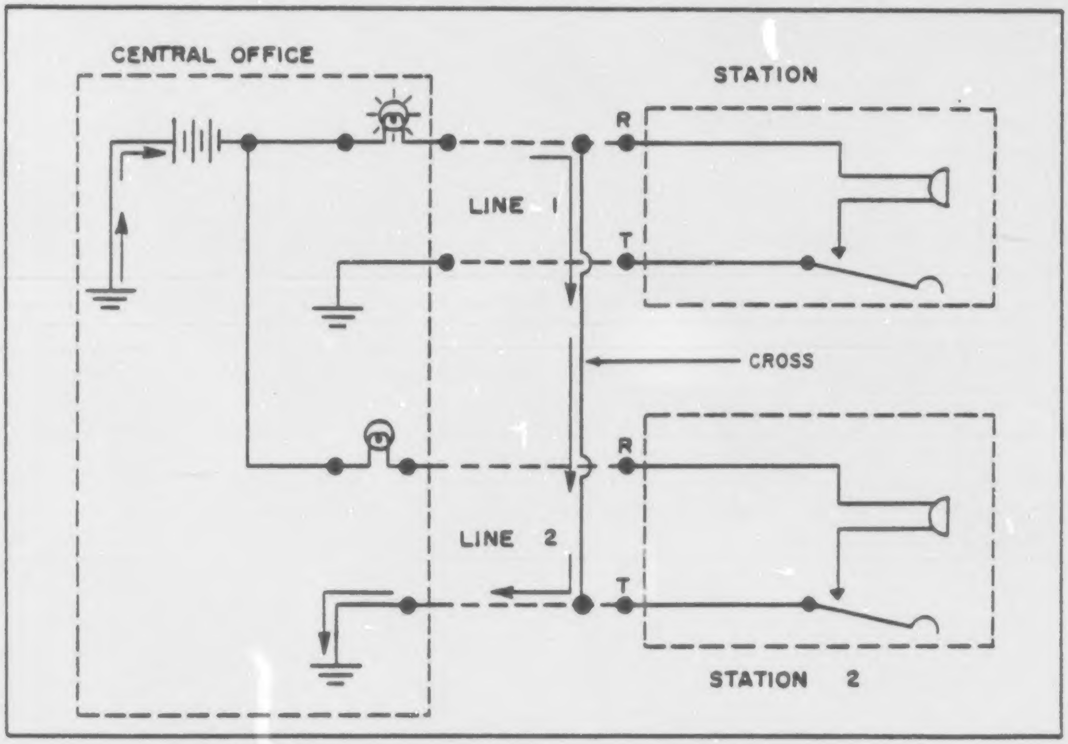

Figure 136. Ring-tip cross.

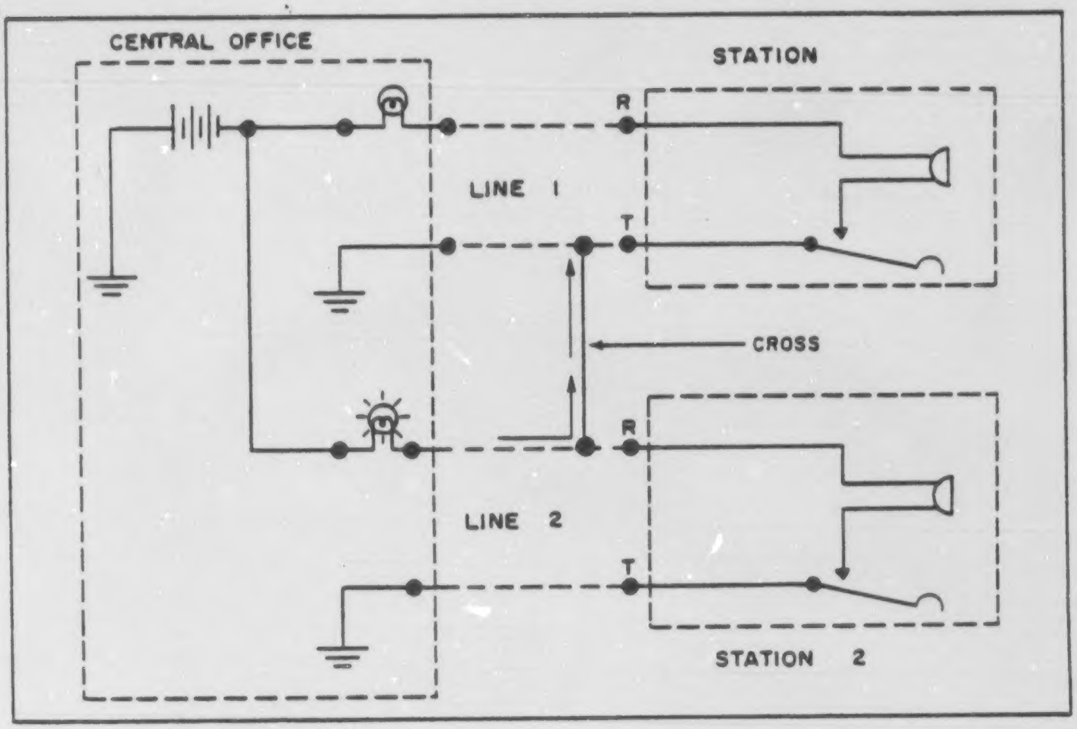

Figure 137. Tip-ring cross.

opens, shorts, crosses, and grounds. An understanding of each type of line fault and the conditions that commonly cause these various faults will make your troubleshooting task relatively simple.

17-7. *Opens.* An open exists when the conducting circuit is broken. It is possible to have situations where the circuit is open intermittently. Therefore, opens are classified as "complete opens" or "intermittent opens." Sometimes, high-resistance connections (connections where poor contact is made) are classified as opens. Below are some conditions that commonly cause opens in drop, block, or station wiring:

- A break in one or both conductors of the circuit.
- A wire disconnected from a terminal.
- An improper or split pair connection at a cable terminal.
- A loose connection at a terminal.
- An improperly made splice.
- A high-resistance connection, caused by the formation of corrosion on the conductors, binding posts, nuts, or terminals.

17-8. A line open causes the telephone set to be dead. We mean by this statement that ringing and talking are not possible. Normally, the telephone user reports this line condition, since an open line circuit appears good at the central office.

17-9. *Shorts.* A short may exist at any piece of apparatus or portion of the circuit. Thus, we may refer to a circuit as being partially or completely shorted. For example, a shorted ringer capacitor in a subset would only partially short the line circuit, but a short from tip to ring of the drop wire would completely short the line circuit. Shorts are often caused by a drop wire with broken insulation; a clamp conducting from one conductor to the other; cable rings wearing through the cable sheath and conductor insulation; high voltage hitting the cable pair, welding the conductor together; dirt or moisture accumulation in terminals, protectors, or connecting blocks; wire tips extending too far and contacting another binding post; and nails driven through the insulation of station wiring.

17-10. A completely shorted circuit causes the telephone subset to appear dead because of the reduced resistance that the short offers to the circuit. A partial short affects the individual apparatus in parallel with it, but the rest of the circuit may be unaffected.

17-11. *Crosses.* A circuit "cross" is the term used to describe the situation when a conductor

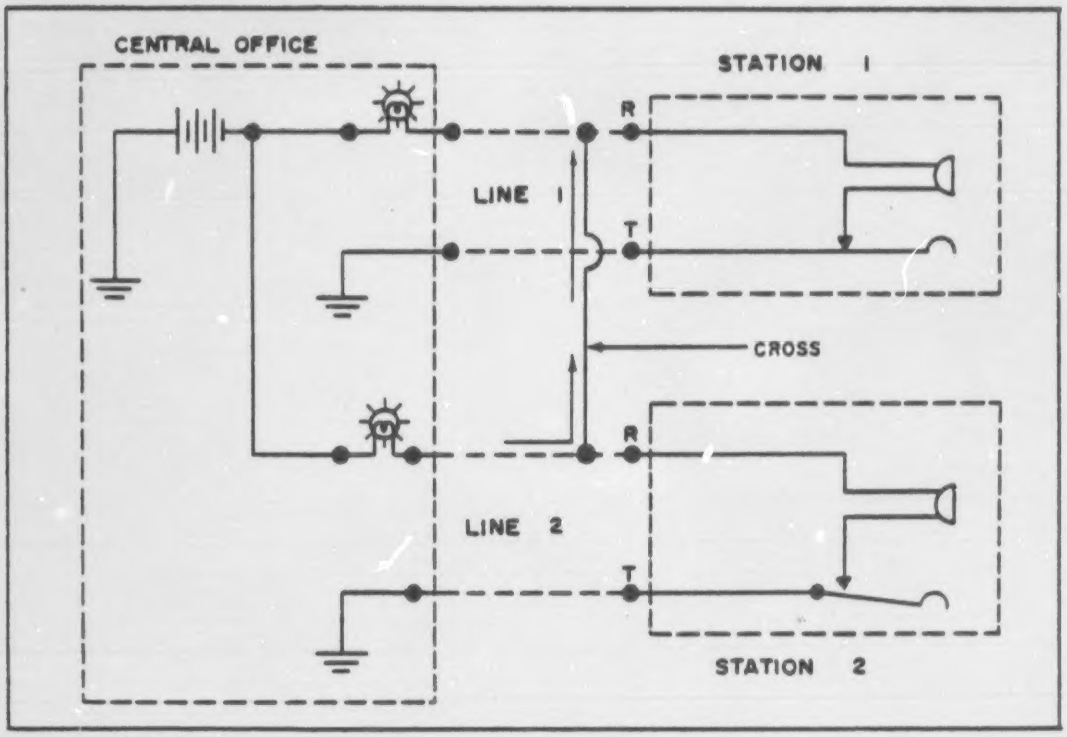
CENTRAL OFFICE
STATION 1
R
LINE 1
T
CROSS
R
LINE 2
T
STATION 2

Figure 138. Ring-ring cross.

from one line pair makes contact with a conductor from another pair. A cross may be caused by a direct contact between adjacent conductors or indirectly through equipment in the central office. There are four types of crosses that can occur in telephone work: ring-tip, tip-ring, tip-tip, and ring-ring, each indicating trouble in the form of ground or foreign voltage. Crosses are caused by the same defects as shorts—moisture, tips too long, broken insulation, and other conditions.

17-12. The ring-tip cross means that the ring conductor of one pair is in contact with the tip conductor of another pair. In this case, ground will be indicated on the ring conductor concerned. The reason for this is that all tip conductors are normally grounded. Therefore, the cross connec-

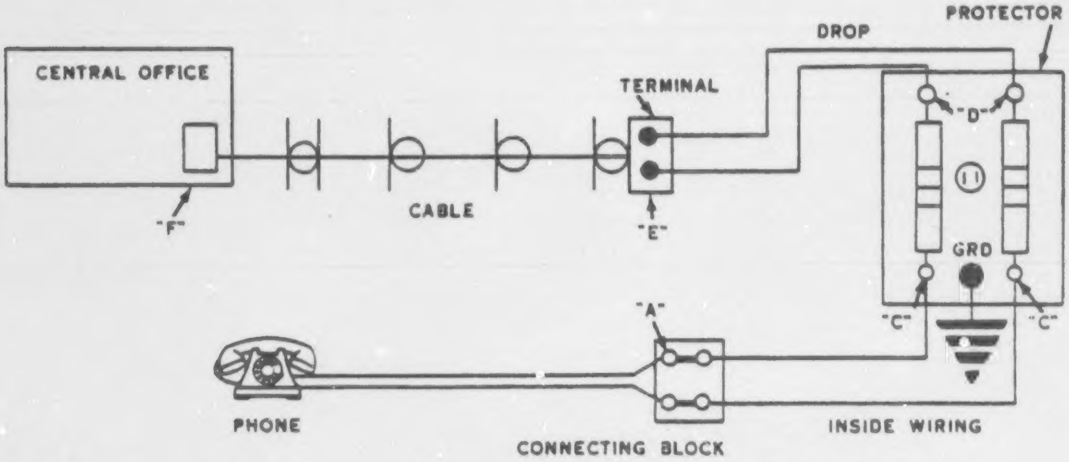
CENTRAL OFFICE
DROP
PROTECTOR
TERMINAL
"D"
GRD
"F"
CABLE
"E"
"A"
"C"
"C"
PHONE
CONNECTING BLOCK
INSIDE WIRING

Figure 139. Subscriber's loop.

tion between ring and tip extends ground to the ring conductor. When the ring conductor is on the pair reported as defective (the pair which you are troubleshooting), the symptoms of trouble in this pair are (1) a permanent signal at the central office, (2) the telephone subset on this pair cannot receive or transmit or can do so only with difficulty, and (3) crosstalk (talk from the other pair concerned) is heard if both lines are in operation at the same time. The exact effect on the telephone subset is determined by the location of the cross. Because of the permanent signal, the central office personnel would most likely report the trouble. The ring-tip cross is illustrated in figure 136 by the line and arrows which indicate a connection from the ring conductor of line 1 to the tip conductor of line 2. By looking at this illustration, you can see how this cross completes a circuit through the central office battery, lighting the signal lamp for line 1 in the central office.

17-13. The tip-ring cross, illustrated in figure 137, is very similar to the ring-tip cross. As a matter of fact, the only difference in the situation between the circuits illustrated in figures 136 and 137 is that the condition between the lines has been reversed. That is, if you were troubleshooting line 1 in figure 136, you would be dealing with a ring-tip cross, and if you were troubleshooting line 1 in figure 137, you would be dealing with a tip-ring cross. If station 1 in figure 137 had reported the trouble, it most likely would have reported crosstalk. This type of cross, however, would light the lamp in the central office for line 2. Therefore, the central office would report the trouble as being in line 2. From these reports and by performing tests, the approximate location of the cross can be determined.

17-14. A tip-to-tip cross does not affect the central office switchboard, and it causes crosstalk only when both lines are operating at the same time. Therefore, this trouble may exist for several days before it is noticed or reported by the telephone subscriber station personnel.

17-15. A cross between the ring conductors of adjacent pairs causes a false signal on one line when a station is operating. You can see in figure 138 that the line lamps in both circuits will operate when the hookswitch at either station is closed. You can also see that the hookswitch in station 1 is closed and the one in station 2 is open. The results would be the same, however, if the hookswitch in station 2 were closed and the one in station 1 were open. When ringing current is sent to either station, it causes the bells of both telephone sets to ring. A ring-ring cross may be reported by either the telephone station or central office personnel.

17-16. *Grounds.* A line ground is a undesirable connection to earth or to conductors which are connected to earth. Most grounds occur at telephone set protectors, where the carbon blocks make contact when high voltage flashes across the 0.003-inch airgap. Foreign particles, such as dust and moisture, often settle between the carbon blocks and establish a conducting circuit to

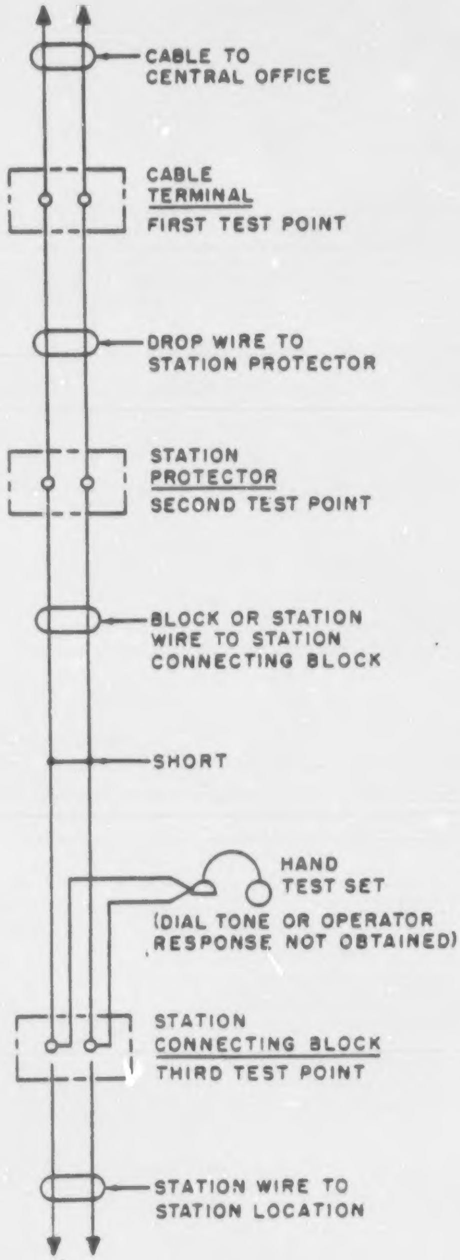
CABLE TO CENTRAL OFFICE
CABLE TERMINAL
FIRST TEST POINT
DROP WIRE TO STATION PROTECTOR
STATION PROTECTOR
SECOND TEST POINT
BLOCK OR STATION WIRE TO STATION CONNECTING BLOCK
SHORT
HAND TEST SET
(DIAL TONE OR OPERATOR RESPONSE NOT OBTAINED)
STATION CONNECTING BLOCK
THIRD TEST POINT
STATION WIRE TO STATION LOCATION

Figure 140. Use of hand test set for trouble isolation.

ground. Line grounds, other than at the protector, are usually the result of damaged insulation which permits the conductors to contact poles, trees, buildings, ground wires, projections, etc. Also, such grounds may be caused by wet station wiring which makes contact to a grounded metallic object.

17-17. The effects of line grounds are dependent upon the type of ground. Three grounded conditions may be found on a line. The tip side of the line or the ring side of the line may be grounded, or a ground may be on both sides which, in effect, is a direct short. The tip side ground may cause noise in the receiver as a result of ac ground returns, power ground returns, and the earth currents being introduced into the line. Such noisy conditions are usually reported by the telephone station personnel. A grounded ring conductor on the line results in a permanent signal at the central office and prevents transmission or signaling by the telephone station. As a result of the permanent signal, this trouble is usually reported by central office personnel. The ground on both sides of the line causes a complete disruption of service; no signal or transmission is possible and a permanent signal is seen at the central office switchboard.

17-18. It is as possible to have intermittent shorts, crosses, and grounds, as it is to have intermittent opens. These intermittent effects are referred to as "swinging" grounds, shorts, etc., while the completely shorted or grounded circuit is often referred to as a "solid" short or ground.

17-19. It is impossible to overestimate the value of a good understanding of the different types of line faults. It is not unusual for an airman who knows the common causes of line faults and is familiar with the installation to go directly to the cause of a reported trouble upon being told the type of fault in a circuit.

17-20. **Testing for Line Faults.** The best way to locate shorts, grounds, opens, or crosses between the terminal and the telephone subset is by using a test set of some kind. Normally, the hand test set is used for testing station lines; however, the type of fault (open, short, cross, or ground) determines how the set is used. Before we consider the testing for each type of fault, let us briefly discuss the preliminary steps required.

17-21. Before the testing in a subset area is started, the repairman should have the following information in order to proceed intelligently and efficiently to locate the cause of trouble:

(1) The telephone number.

(2) The location of the set, given in sufficient detail to permit ready identification of the premises (such as the floor, room number, etc.).

(3) Cable number, pair number, and terminal.

(4) The pole number on which the drop wires terminate (on other than cable lines) if available.

(5) Transmission quality, if any.

(6) Nature of the trouble as diagnosed by test or from a report.

(7) Whether or not the station is out of service.

(8) Other items of special information such as:

- *(a)* Any indication that foreign current is on the line.
- *(b)* Is the service at fault for a hospital or doctor's office?
- *(c)* Has that trouble or one similar occurred recently on the same line?
- *(d)* Should the entire line from the terminal to the station be inspected?

17-22. The first step in locating line faults is to verify the information given you. Take nothing for granted; always check the line to be sure that the trouble is as reported. The next step is to determine if the trouble is in the cable or in the installation wiring. If the fault is in the cable, report the condition to your wire chief or test desk. Another pair may be assigned for the circuit. If the trouble is in the installation wiring, determine what part of the wiring contains the fault. This procedure of elimination is sometimes referred to as trouble isolation. To carry out this procedure, make the first test at the station protector and proceed in the direction of the trouble to the next convenient test point.

17-23. For purposes of clarification, it might be well to go through the initial testing process. Using figure 139 as a reference, assume that there is a line fault between the central office and the telephone. The objective is to isolate the fault:

(1) Remove the fuses from the protector and test back towards the central office (D toward F). If the test indicates the trouble to be between D and F, proceed from the protector to the terminal E.

(2) Now, remove the drop wire from the terminal binding posts and test toward the central office again (E to F). If E to F is clear of trouble, the fault must be in the drop wire. NOTE: If in making the first test at the protector (step1), you found the trouble to be in the station wiring, replace the fuses in the protector and proceed to the connecting block A.

(3) Remove the line wire from the connecting block and test back toward the station protector (A to C). If the line is good, the fault lies in the instrument or cords. However, if the line from

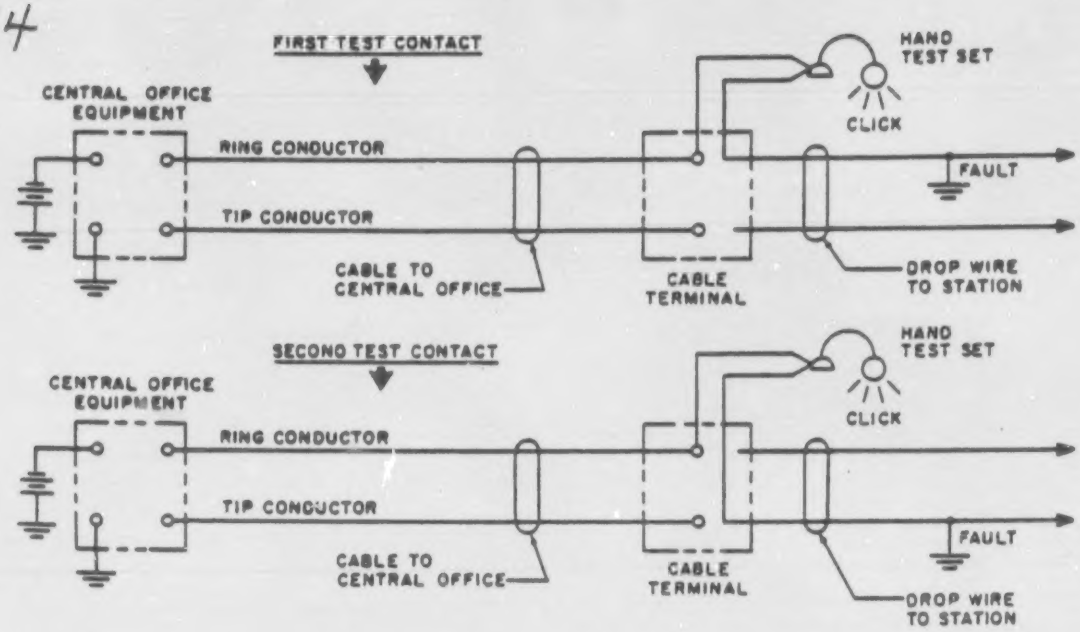
FIRST TEST CONTACT
CENTRAL OFFICE EQUIPMENT
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
CABLE TERMINAL
HAND TEST SET
CLICK
FAULT
DROP WIRE TO STATION
SECOND TEST CONTACT
CENTRAL OFFICE EQUIPMENT
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
CABLE TERMINAL
HAND TEST SET
CLICK
FAULT
DROP WIRE TO STATION

Figure 141. Test point for isolation of ground.

A to C tests faulty, the trouble is in the station run.

17-24. The testing process can just as well be started at the terminal instead of the station protector, but select points where disconnections can be made readily, such as binding posts, bridging connectors, connecting block, etc. In general, no wires are to be cut until the tests have isolated the fault between two adjacent points. Then, after an inspection has been made, one conductor of the wire may be cut to make the test. It is wise to start your testing from the most convenient place; you might save one trip up the pole if you start at the protector. Remember, too, a quick inspection for broken wires is always advisable before beginning the tests. The test set across the tip and ring of the line should respond with a click each time the connection is made and broken. The absence of a click indicates an open in the line.

17-25. *Testing for shorts.* As mentioned before, shorts in drop, block, or station wiring are caused mainly by damage to the insulation when the wires are in contact with supporting fixtures, pole or building attachments, and trees or other obstructions along the wire route. Shorts are also caused by dirt or foreign material that has accumulated in terminals, protectors, and connecting blocks. Shorts caused by dirt in terminals and at other interconnections and those caused by dampness penetrating damaged insulation are usually high resistance shorts which can be more readily detected in wet weather, because then they are usually more pronounced.

17-26. The procedure for isolating shorts is the same for both high-resistance and low-resistance shorts. With high-resistance shorts, however, the test deskman, by using central office test equipment, can more accurately guide and direct the repairman to the location of the fault.

17-27. To isolate a shorted section of the drop and station wiring installation, test the line at the cable terminal and at successive terminating points. You can start at the cable terminal and work toward the station end of the line (fig. 140); however, many experienced repairmen start at the protector. Use a hand test set to make each test as follows:

(1) Disconnect the wire leading toward the station.
(2) Bridge the test set leads across the terminals.
(3) Listen in the test set receiver for either dial tone or operator response.

17-28. If dial tone or operator response is obtained, the line may be considered good up to the test point. So reconnect the wire leading toward the station end of the line and proceed to the next test point. If dial tone or operator response is not obtained at any test point, the short is in the section of line between that test point and the previous test point. The short may then be further isolated by a close visual inspection to locate the probable defect in the wiring or by cutting the wire at selected points and conducting further tests with the hand test set. If the line is old or the tested section is short, it is common practice to replace the whole section.

17-29. When the test at the cable terminal indicates that the short is in the cable, report to the test deskman for further instructions.

17-30. *Testing for grounds.* Grounds in drop, block, and station wiring are usually caused by damage to the insulation when the wires are in contact with poles, trees, guys, buildings, cables, ground wires, rainspouts, building projections, or other structures.

17-31. To isolate the section of the line in which the ground is located, test the line at the cable terminal and at successive terminal points along the line. Start at the cable terminal and work toward the station end of the line. Use a hand test set (see fig. 141) to make each test as follows:

(1) Disconnect the station leads of the line under test from the terminal post at the test location.

(2) Identify the ring side of the line.

(3) Clip one of the test set leads to the terminal post on the ring side of the line.

(4) Touch the free lead of the test set to each of the disconnected leads in turn.

(5) Listen in the receiver of the test set for a battery click on the make and break of each contact.

17-32. A battery click on the make and break of either of the test contacts indicates that a gound on the station side of the test point has completed a path for current from the central office battery to ground.

17-33. A battery click on the make and break make and break of any of the test contacts at any test point indicates that the ground is in the section of the line between that test point and the previous test point. If you do not hear a battery click during tests conducted at a cable terminal and you cannot trace the ground to a faulty condition in the terminal, then you must assume that the fault is in the cable, and you should contact the test deskman for further instructions.

17-34. Sometimes you cannot isolate high-resistance grounds with the hand test set. So have the test deskman test the line while disconnections are made at the various terminal points.

17-35. After the ground has been isolated to one section of the substation, it may be further

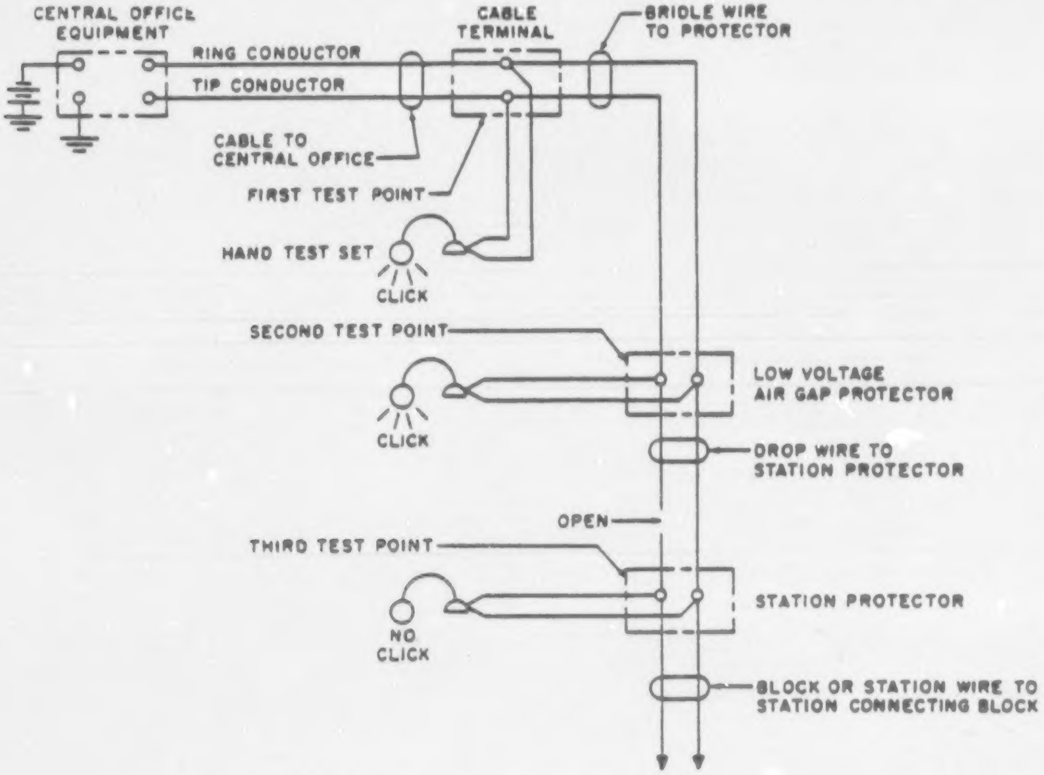
CENTRAL OFFICE EQUIPMENT
CABLE TERMINAL
BRIDLE WIRE TO PROTECTOR
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
FIRST TEST POINT
HAND TEST SET
CLICK
SECOND TEST POINT
LOW VOLTAGE AIR GAP PROTECTOR
CLICK
DROP WIRE TO STATION PROTECTOR
OPEN
THIRD TEST POINT
STATION PROTECTOR
NO CLICK
BLOCK OR STATION WIRE TO STATION CONNECTING BLOCK

Figure 142. Test point for isolation of open.

isolated by a close visual inspection or by more tests. The repairman can decide the need for specific fault location, which is now apparent for any particular job.

17-36. *Testing for opens.* Opens are usually caused by one of the following conditions:

- A break in one or both conductors in the wire.
- A wire disconnected from a terminal.
- An improper or split-pair connection at a cable terminal.
- A loose connection at a terminal.
- An improperly made splice.

17-37. To isolate the section of line in which the open is located, test the line at the cable terminal and at successive terminal points along the line, starting at the cable terminal and working toward the station end of the line. Make each test by bridging a hand test set across the terminals of the circuit under test and listening for a battery click in the receiver of the test set (fig. 142). As in previous tests, if no click is heard, the open is between the test point and the previous test point. If you do not hear a battery click during tests at a cable terminal and you cannot trace the open to a faulty connection in the terminal, you can assume that the fault is in the cable. In such a case, contact the deskman for further instructions.

17-38. To isolate an intermittent open, move and shake the wires in the section of the line that is on the central office side of the test location. A succession of battery clicks or a fluttering noise in the receiver of the test set indicates that the open is in the section of the line under test. If the fault cannot be isolated by such action, a careful visual inspection of the line, particularly at terminal point connections, will usually disclose the faulty condition.

17-39. High-resistance connections are usually caused by improper cleaning of the conductors at terminals or by the formation of corrosion on the conductors, binding posts, nuts, or washers at the terminal. When isolating high-resistance connections, bridge the test set across the conductors or the station side of the termination and listen for noise. If you cannot definitely isolate the fault to any specific connection, disconnect, clean, and reconnect the conductors at all terminal points and retest the line.

17-40. After you have isolated an open to one section of the drop or station wire plant, you may further isolate it by a close visual inspection or additional tests to specifically locate the defect. Any need for further isolation or specific location of a fault in a section of wire will be determined by the repair procedures you have selected.

17-41. *Testing for crosses.* Figure 143 shows all four types of crosses that can occur in telephone circuits and the test set connection for each cross that results in an audible response. To make any of these tests, both wires of one of the crossed lines must be disconnected from the terminal binding posts. These wires must be placed in a position so that they can be properly connected upon completion of the tests. After the wires have been disconnected, one clip of the test set must be connected to one binding post, as shown in figure 143. Then, the other clip must be touched to the disconnected wires in turn. If a click occurs, you can see that the wire causing the click is crossed with another line and the cross is near the point where you are making the check. If no click is heard, then the one test clip must be transferred to the other binding post and the test repeated by again touching the other test clip to the disconnected wires. If no clicks are heard on either test, the cross is not located in this part of the circuit.

17-42. Testing for a cross in a cable containing several pairs may sometimes be rather deceiving. What appears to be crossed circuit may actually be a short. You must remember that a cross involves two circuits, or two pairs. The click that is heard when testing may be caused by either of two conditions: the pairs may be shorted or the line under test may be crossed with an adjacent pair. By performing tests for both crosses and shorts, the trouble can usually be isolated.

18. Trouble Elimination

18-1. The type of repair that is required for a particular substation trouble must, of course, be determined by the type of trouble and its location. In each case, the repair required is a repetition of the installation steps. Probably a connection was not cleaned and scoured or maybe a wire is damaged.

18-2. **Wire Portion of the Circuit.** Repairing wire breaks or other damage depends upon the location of the damage. After you have isolated the fault to a particular section of the installation, you must then find its specific location. In most cases, it is possible to pinpoint the exact location of the fault by a careful inspection of the wire involved. In cases of swinging or high-resistance faults, make sure that all connections are tight and clean. Faults located in sections of drop, be cut out and a ng that the installine that has detefurther trouble ape replaced with a cause cannot be removed, such as a building obstacle or trees, relocate the line adjacent to that point.

18-3. **Other Components.** If the trouble is traced to the protector, check the fuses and inspect the carbon blocks. If the carbon blocks are damp, wipe them dry; in some cases, you may

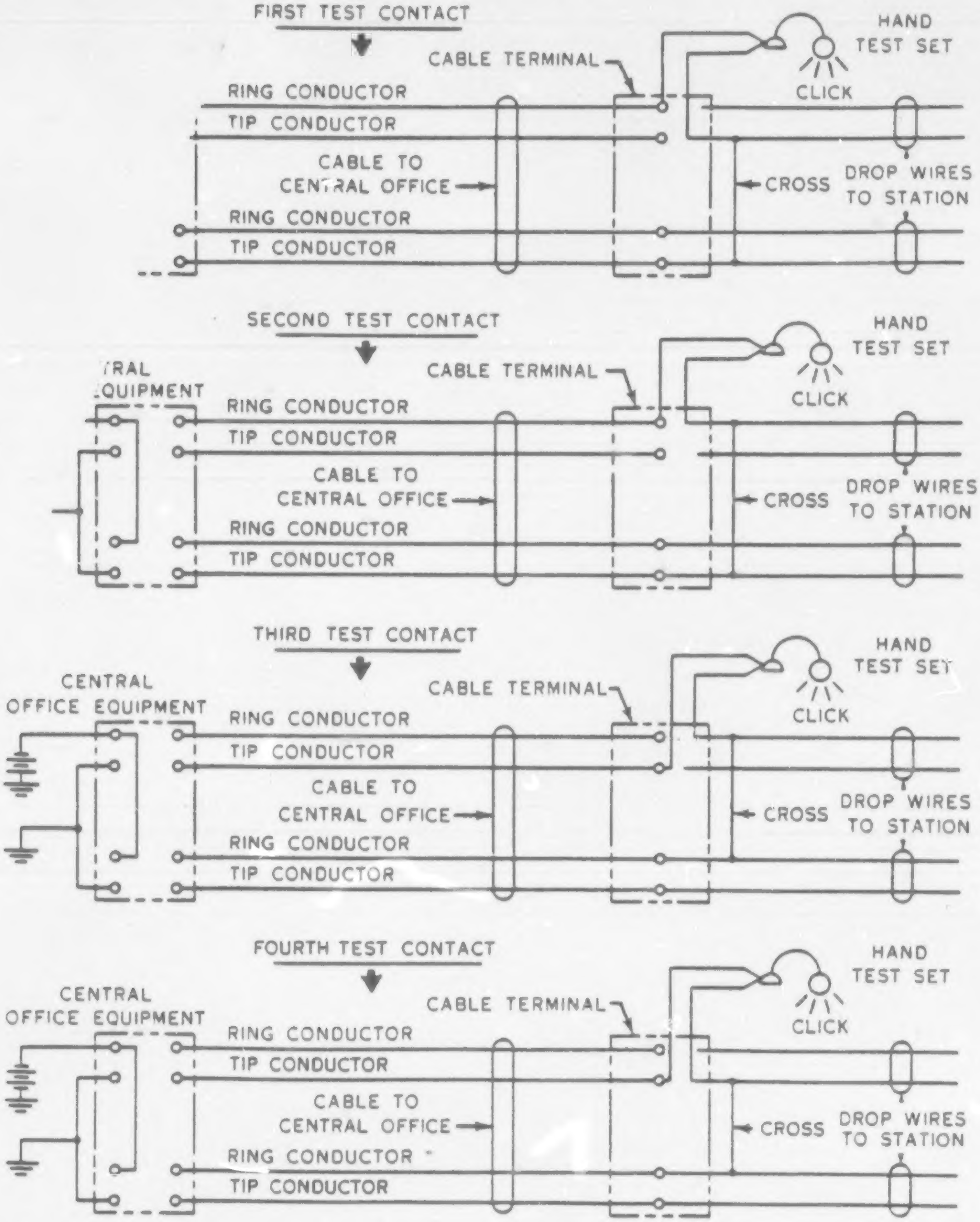
FIRST TEST CONTACT
CABLE TERMINAL
HAND TEST SET
CLICK
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
CROSS
DROP WIRES TO STATION
RING CONDUCTOR
TIP CONDUCTOR
SECOND TEST CONTACT
'RAL
.QUIPMENT
CABLE TERMINAL
HAND TEST SET
CLICK
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
CROSS
DROP WIRES TO STATION
RING CONDUCTOR
TIP CONDUCTOR
THIRD TEST CONTACT
CENTRAL OFFICE EQUIPMENT
CABLE TERMINAL
HAND TEST SET
CLICK
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
CROSS
DROP WIRES TO STATION
RING CONDUCTOR
TIP CONDUCTOR
FOURTH TEST CONTACT
CENTRAL OFFICE EQUIPMENT
CABLE TERMINAL
HAND TEST SET
CLICK
RING CONDUCTOR
TIP CONDUCTOR
CABLE TO CENTRAL OFFICE
CROSS
DROP WIRES TO STATION
RING CONDUCTOR
TIP CONDUCTOR

Figure 143. Schematic diagram of tests for a cross.

have to relocate the protector to avoid these conditions. If the carbon blocks are dirty or pitted, determine whether cleaning or replacing them is the better maintenance practice. If your decision is to clean them, be careful that you do not increase the airgap between the blocks.

18-4. Connecting blocks seldom cause service interruptions unless they are struck by an object which dents the cover or breaks the base. These troubles are easily corrected by replacing the damaged parts. If the inside wiring is grounded or broken, it may be repaired by splicing; however, if it has deteriorated, it should also be replaced.

18-5. When the trouble is found to be in the cable or line, you must then report the situation to the central office. In this case, the wire chief will usually assign another pair (if available) for use with the station on which you are working.

18-6. This ends the final chapter of Volume 3. Complete the last group of chapter review exercises and review the material in the book to prepare yourself for the volume review exercises.

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TELEPHONE EQUIPMENT INSTALLER-REPAIRMAN

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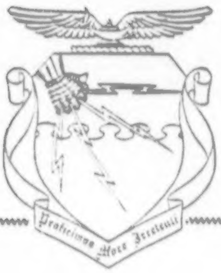
Volume 4

Key Systems and Intercommunications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Extension Course Institute
Air University

180

Acknowledgmemt

Acknowledgment is gratefully extended to the American Telephone and Telegraph Company and to Bell Telephone Laboratories for the copyrighted schematic diagrams shown in figures 26, 41, and 43 and foldouts 1 through 7.

Preface

MOST communications systems are developed around the basic electrical principles; therefore, a repairman with a good knowledge of one communications system should soon be able to learn the features of a second. You should be able to give good equipment service if you can trace and analyze communications circuits. An efficient repairman understands the theory and the normal function of each circuit in the system. That understanding permits his intelligent analysis of equipment trouble.

Since the objective of communications maintenance is to insure accurate, rapid, and prolonged operation of Air Force equipment, delays must therefore be held to a minimum. Consequently, when trouble comes, the service is to begin immediately and must be completed as soon as possible.

This volume describes the varied uses of key and intercommunicating systems. Also, it describes operating principles of exemplary equipment, thus giving procedures that apply to most systems. The example method is also used in describing installation, trouble analysis, and maintenance. Notation is made of the comparison between equipments, circuit principles, installation methods, and maintenance requirements described in other volumes.

This "home study" CDC, with the skill training you get during OJT, will broaden your knowledge and prepare you for complex tasks. You should realize that complex tasks are often a union of simple tasks; hence, by completing simple assignments, you help solve a complex problem. When you need an answer to a question, ask one of the experienced installer-repairman team members. A qualified technician is willing to help a trainee who is sincere in wanting to know—because the former understands that "knowing" is required of a capable member on the team.

At the end of this volume is a glossary, which defines many terms or words that are related to your job. Use it.

There are seven schematic foldouts with this volume. Foldouts 2, 4, 5, and 6 are in the back of the volume. Foldouts 1, 3, and 7 are included as separate inserts.

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Introduction to Key Systems and Intercommunications

NOT TOO MANY years ago a picture of a busy executive usually included a huge desk with several communications instruments. Their number and types gave you an indication of how important he was. In the same office today you see a different picture. One or two sophisticated instruments have replaced the many individual units, and the system is tailored to meet the special requirements of that particular office.

2. When a communications system is properly installed, the work of the using organization is simplified because such a system can save many steps and much time. The use of intercommunications systems, key telephone equipment, and private branch exchange (PBX) switchboards saves cable, instruments, and central office equipment. Because of these savings, base communications personnel can increase the telephone service of using organizations.

3. A variety of communications systems are in wide use by the Air Force. Individuals in the telephone equipment installer-repairman career field are responsible for the installation and maintenance of this equipment. We will discuss several systems in use at Air Force installations. This information will help you understand the operations, installation, and maintenance of these communications systems.

1. Key Telephone Systems

1-1. Modern key telephones, in addition to providing specialized telephone service, present a better appearance and are more economical and versatile than the telephones used with the original systems. The former systems provided a specialized telephone service, but the stations were limited to a set arrangement because the features were grouped in certain combinations to form systems. The features included: pickup, hold, intercom, cutoff, and signaling. The present systems have all the advantages of the superseded system, but they also can have additional features. An example of the possible diversification is seen by considering a base commander's key telephone and that of his receptionist. His unit may have an exclusion key, and hers may require a greater number of keys. You must consider each station as a separate problem and then select the equipment that satisfies the needs at each station.

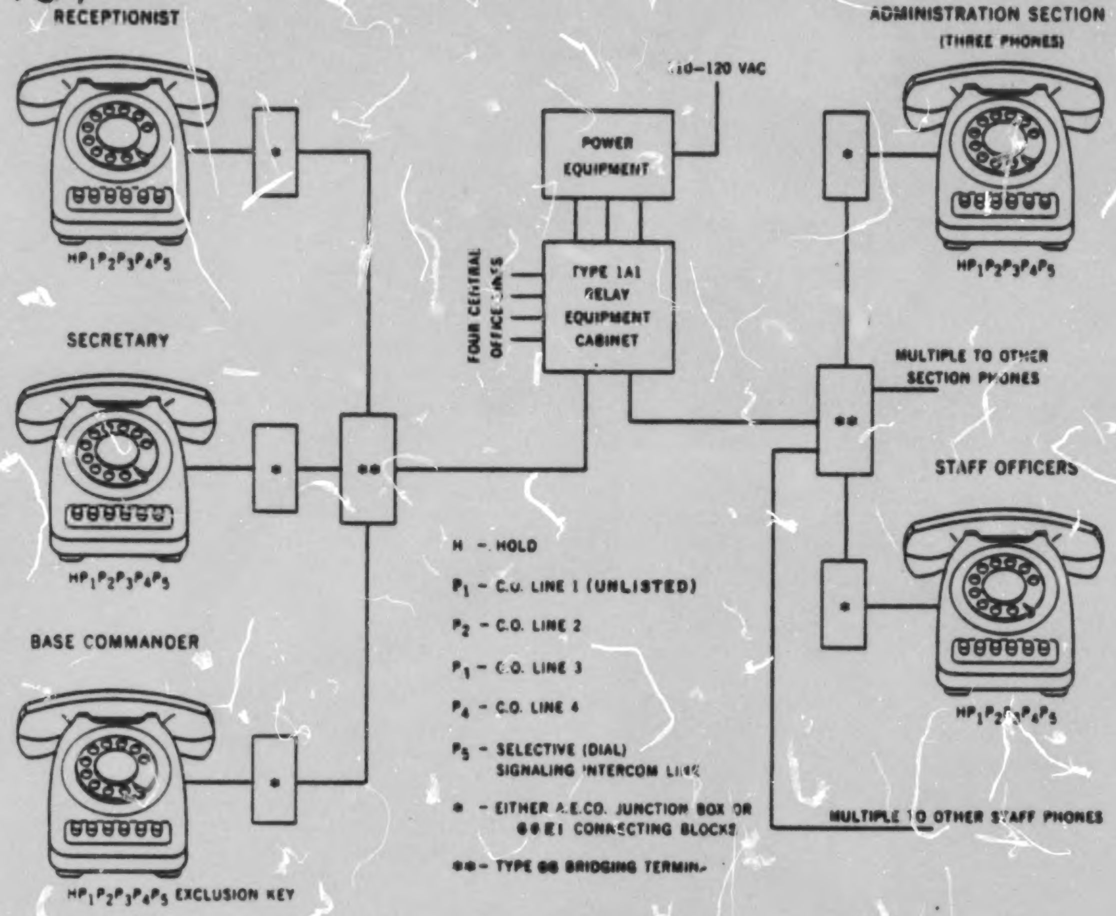
1-2. The Air Force now uses 1A1, 1A2, and 6A key systems extensively; but key equipment is continually being expanded, modified, and improved. Consequently, you need to be prepared for variations in circuitry. This section will help you to understand the operation, installation, and maintenance of any key system.

1-3. Type 1A1 Key System. The 1A1 key system compares with a PBX in that the talking circuits are connected by an operated key. Of course, in this system the user operates the key, whereas an attendant operates the PBX keys. The typical system includes three to seven talking circuits distributed among 5 to 15 stations.

1-4. One big advantage of the 1A1 system is its flexibility. Probably no two installations are exactly alike in all service provisions. The talking circuits of a system may connect directly to a central office, a PBX, or a similar telephone system. A circuit is also available for a local intercom system with visual and audible supervision at each station.

1-5. Many other services may be provided by adding a particular unit to the installation. We use a typical 1A1 key telephone system (shown in fig. 1) for our explanation.

1-6. It is evident in this figure that the system consists of telephones, connectors, bridging terminals, a relay cabinet (which contains key units), and a power supply. The illustrated system has seven stations. Each


RECEPTIONIST
$HP_1P_2P_3P_4P_5$
SECRETARY
$HP_1P_2P_3P_4P_5$
BASE COMMANDER
$HP_1P_2P_3P_4P_5$ EXCLUSION KEY
110–120 VAC
POWER EQUIPMENT
FOUR CENTRAL OFFICE LINES
TYPE 1A1 RELAY EQUIPMENT CABINET
ADMINISTRATION SECTION
(THREE PHONES)
$HP_1P_2P_3P_4P_5$
MULTIPLE TO OTHER SECTION PHONES
STAFF OFFICERS
$HP_1P_2P_3P_4P_5$
MULTIPLE TO OTHER STAFF PHONES
H - HOLD
P_1 - C.O. LINE 1 (UNLISTED)
P_2 - C.O. LINE 2
P_3 - C.O. LINE 3
P_4 - C.O. LINE 4
P_5 - SELECTIVE (DIAL) SIGNALING INTERCOM LINE
* - EITHER A.E.CO. JUNCTION BOX OR 66E1 CONNECTING BLOCKS
** - TYPE 66 BRIDGING TERMIN-

FEATURES

1. Four central office lines: P_2, P_3, and P_4 listed and intended primarily for incoming calls; P_1 unlisted and intended primarily for outgoing calls.
2. All telephones equipped with holding feature to facilitate transfer of calls and promote accuracy in handling of customer inquiries.
3. One dial intercom line, P_5, with line flashing for use by receptionist in forwarding calls and for general office purposes.
4. Base Commander's telephone equipped for exclusion on central office line, P_1.

HL-086

Figure 1. Key system layout.

telephone, through its connections and terminals, has access to four central office lines and one intercom line. Each circuit works because of the relay units of the equipment cabinet. A close examination of the individual components is necessary if we are to understand the system. Let us first examine the telephones of the system.

1-4. *The 565 key telephone.* The 565 telephone is one in the 560 series of key telephones. The Air Force has many variations of several key telephones. We have chosen the 565 for our discussion because it adequately represents the 560 series key telephones. Essentially, it is a 500 type telephone, discussed in a previous volume, with addition of the circuits for the keys. The talking, ringing, and receiving circuits are the same as those of the 500 type. These key telephones have keys for pickup, holding, signaling, cutoff, and intercom. The keys are located in the lower front part of the telephone set and are illuminated for signaling and for busy indication. When more than one line terminates in a set, the ringer may be connected to any one line or, with additional

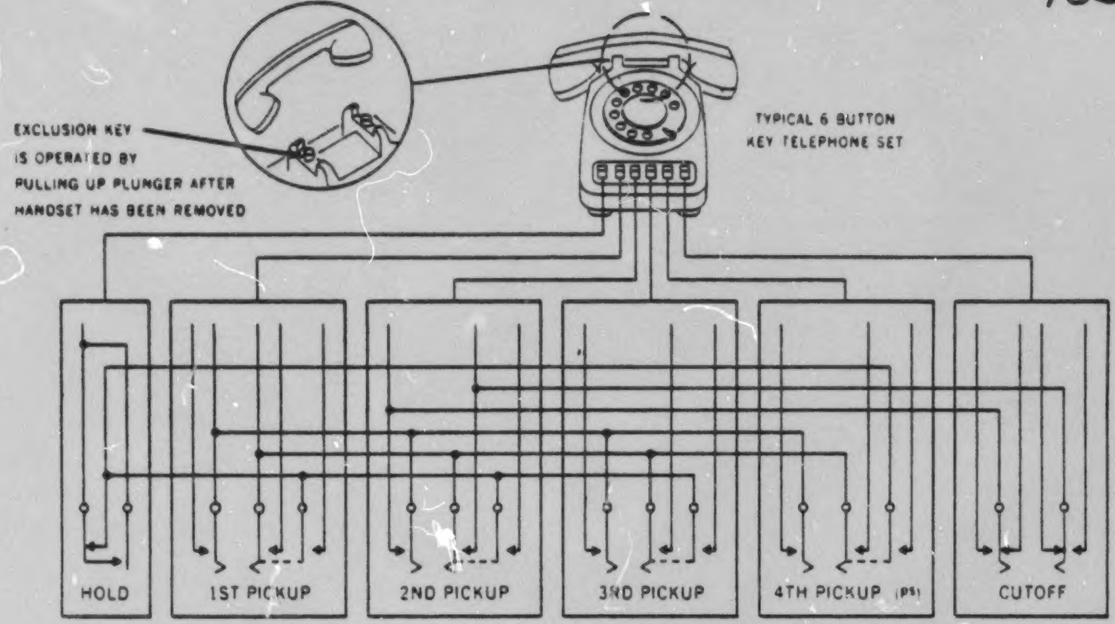

EXCLUSION KEY IS OPERATED BY PULLING UP PLUNGER AFTER HANDSET HAS BEEN REMOVED
TYPICAL 6 BUTTON KEY TELEPHONE SET
HOLD
1ST PICKUP
2ND PICKUP
3RD PICKUP
4TH PICKUP (PS)
CUTOFF

Figure 2. Key telephone set pushbutton and switch arrangement.

equipment, be made common to all lines. All Mounting Cards have amphenol connectors.

1-8. The pushbuttons shown below the dial in figure 2 (which is an illustration of a base commander's set) move springs on keys placed below them. These springs are also illustrated in figure 2. The PICKUP keys switch the set's talking circuit to one line. The depressed pushbutton locks down and, in addition, restores any other depressed pushbutton to the normal position. Thus, an interlocking device between the keys prevents two keys from being operated simultaneously. A lamp within the operated pushbutton glows

KEY BUTTON ARRANGEMENTS	FEATURES					CODING		
	EXCL KEY	ILLUMINATED KEY BUTTONS	STATION BUSY LAMP CONTROL	SPEAKERPHONE CONTROL	PLUG-IN CORDS	MANUAL	DIAL	RATING
HPPP						540BA	540BB	MD
HPPP		X				544BA	544BB	MD
HPPP^s	X	X	X			545BA	545BB	MD
PPPP^s		X				544AA	544AB	MD
HPPPPP		X				564BA	564BB	MD
HPPPPS		X				564CA	564CB	MD
HPPPSS		X				564DA	564DB	MD
HPPP^{s}P^{s}P^s		X	X			564HA	564HB	MD
HPPP^{s}P^{s}P^s	X	X	X			565BA	565BB	MD
HPPP^{s}P^{s}P^s	X	X	X	X		565HA	565HB	MD
PPPP^{s}P^{s}P^s	X	X	X			565AA	565AB	MD
PPPP^{s}P^{s}P^s	X	X	X	X		565GA	565GB	MD
HPPPP^{s}C	X	X	X			565EA	565EB	MD
HPPPP^{s}C	X	X	X	X		565LA	565LB	MD
HPPP^{s}P^{s}C	X	X	X	X	X		565LD	
HPPP^{s}P^{s}P^s		X	X	X	X		564HD	
HPPP^{s}P^{s}P^s		X	X		X		564HL	
HPPP^{s}P^{s}P^s	X	X	X	X	X		565HK	
HPPP^{s}P^{s}P^s	X	X	X		X		566HF	

H = Hold (Nonlocking)
P = Pickup (Locking)
S = Signal (nonlocking)
C = Cutoff (Turn button)
P^s = Convertible, either pickup (locking) or signaling (nonlocking)

Figure 3. Identification codes for key telephones.

to indicate the busy condition. By pressing the HOLD pushbutton, you keep the line connection while performing another function. Release of the HOLD pushbutton restores the operated PICKUP pushbutton. The figure includes an explanation on the operation of the EXCLUSION key, which permits the user to cut out all stations of that system for that central office line. Exclusion is normally effective on only the line connected to the first PICKUP key. Following the operation of this key, the operator of the key can talk on an outside line without being heard or interferred with by other persons in the system.

1-9. The 565 key telephone is identified

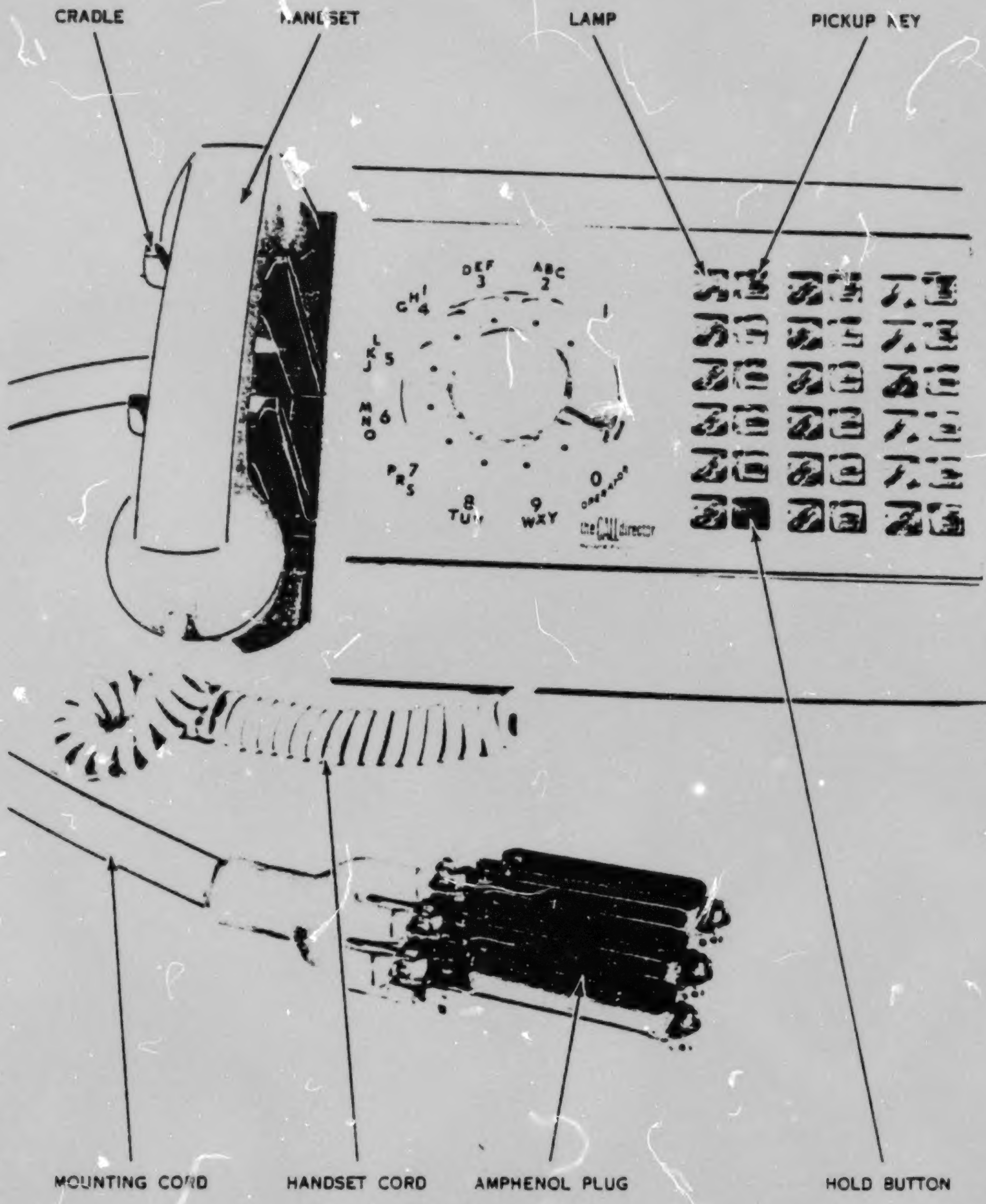

CRADLE
HANDSET
LAMP
PICKUP KEY
the Call director
MOUNTING CORD
HANDSET CORD
AMPHENOL PLUG
HOLD BUTTON

Figure 4. Call Director set.

by a code. Figure 3 illustrates its code and its features. The identification number contains two or three letters, in addition to three digits. Each digit and letter indicates a characteristic of the set. For example:

- First digit. The 5 of this position indicates that the set has the components of the 500 type telephone.
- Second digit. The second digit is always a 0, 1, 4, or 6 and indicates the number of pushbuttons on the set. There were a few sets having 7 as a second digit. This set had three PICKUP keys, three HOLD keys, and one key for operating a buzzer circuit.
- Third digit. The third digit is always a 0, 1, 4, 5, or 8 and indicates some of the features built into the set. Other features are indicated by letters.
  (1) A 0 indicates that the set has neither exclusion nor lamps.
  (2) A 1 indicates exclusion but no lamps.
  (3) A 4 indicates lamps but no exclusion.
  (4) A 5 indicates lamps and exclusion.
  (5) An 8 indicates that the set is designed for use with 4-wire service.

- First letter. The first letter indicates the arrangement of the keys. This letter is arbitrarily assigned and has no significance except as assigned in the identification chart. As an example, the first letter, L, for the 565LB telephone indicates that the phone has CUTOFF and HOLD buttons. Also, it indicates that the phone is usable with "hands off" equipment.
- Second letter. Originally, the second letter indicated whether the set was constructed with or without a dial. An "A" identified it as manual type and a "B" identified it as having a dial. All sets are now shipped with a dial, hence no code is needed. Of course, you may see sets that have the former identification. The second letter on the most modern sets will indicate another variation which may have different meanings. Again, the manufacturer determines the indicator and its meaning.

NOTE: Touch-tone telephone coding differs from what we have shown in figure 3. The 1564HL is one of these telephones. In this case the 1 indicates that the telephone is a touch-tone type (using pushbuttons for dialing). It also has one HOLD and five PICKUP keys, as indicated by the 6. The 4 indicates some of the features of the set, and the letters reveal other features. This telephone won't work with the 207C dial intercom unit; thus it must be used with a touch-tone adapter unit if the 207C is a part of the system.

1-10. Since almost any desired feature combination can be furnished to a station, you should study your requirements and select the equipment that meets those needs. Let us consider the features of the sets illustrated in figure 1.

1-11. It is evident that the communications officer ordered for the base commander a set containing the EXCLUSION key, a HOLD pushbutton, and five PICKUP keys. Figure 3 shows us that this set must be 565HK (565HB and 565GB, having most of the same features are no longer being manufactured, as indicated by the MD in the rating column). However, the exclusion switch for the set would have to be ordered separately although the plunger would be in the telephone case. In addition, figure 1 discloses that key P_1 is connected to an unlisted central office line. Since the line is not listed in the directory, few incoming calls will be received through this circuit. Consequently, as stated in figure 1, the line is intended primarily for outgoing calls. Of course, the outgoing and incoming lines could have been assigned to any of the "P" keys.

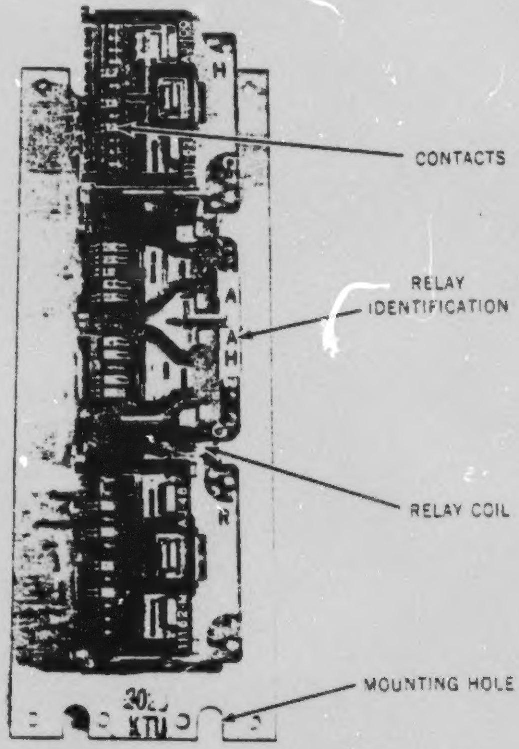


Figure 5. 202D line unit.

The remaining telephones of figure 1 have no exclusion feature; therefore they are coded 564HD. All of the telephones have the hold feature; thus the user can answer a call on a line without disconnecting a second line that has a call in existence.

1-12. Figure 3 reveals two additional features for key systems. The cutoff feature is a circuit device which permits the user to disconnect an extension or an extension ringer. The signal button allows the station occupant to signal another station within the system by simply holding the key down. Removing your finger from the button allows the button to restore. All stations must have an audible signaling device. For a less noisy signal, you may install a buzzer instead of a ringer. When lamps are used, a steady glow indicates that the call has been answered or is an outgoing call. A flashing lamp indicates that the call is incoming. A visual signal is also provided in conjunction with a HOLD pushbutton: This lamp operation is referred to as a "wink." (The "wink" feature provides a long ON period and short OFF period.)

1-13. Call Director or Call Commander. Another multibutton phone used extensively is the Call Director, Made by the Western Electric Company (WECO). It provides the same services as the 560 series telephone. However, it will accomodate up to 30 lines. The most commonly used sets are the 630 and 631. The 630 type comes equipped with 12 lines, but can be expanded to 18 by the addition of a 598A as shown in figure 4. The 631 may be expanded to 30 buttons. The Auto Electric Company makes an equivalent set, the Call Commander. Thus, either set is in reality only a key telephone with 12 or more buttons instead of 6. The talking circuits of the Call Director set are identical to those used in the 560 series sets. There is a difference in the construction of the switches operated by the pushbuttons, but the job they do is the same.

1-14. Either the Call Director or Call Commander can be used with the 1A1 system. When used with this system it is generally used by a receptionist who answers all calls. The system will have to be large to make the use of the Call Director economical. Sometimes, it is used in combination with two or more systems, with one attendant answering all calls and using the intercom feature to distribute the calls to those concerned. Some Call Directors are designed to accept either two or four wire circuits; however, we will not have time to discuss individual sets.

1-15. *Key telephone units.* If you refer

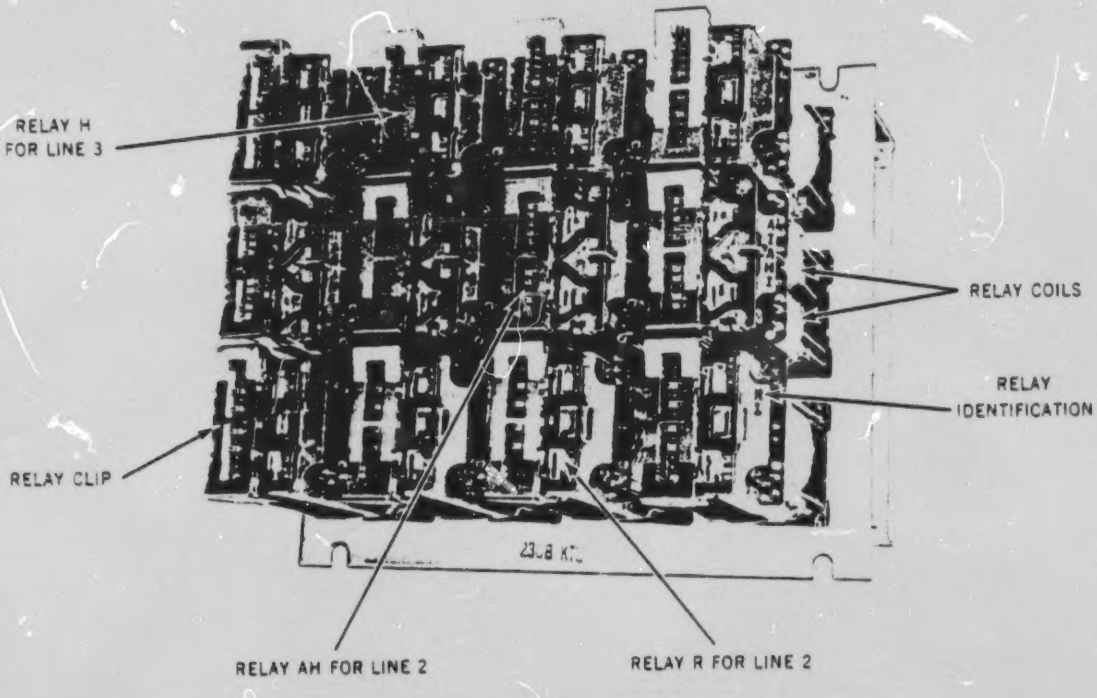


Figure 6. 230B combined CO or PBX line unit.

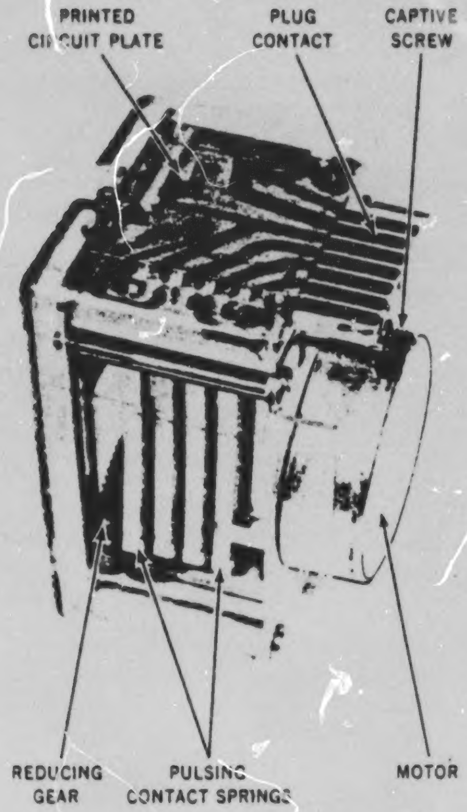


Figure 7. KS-19175 interrupter.

again to figure 1, you can see that the incoming central office lines are connected to an apparatus and unit cabinet. This cabinet protects the key units and provides a mounting which allows access to the key telephone units (KTUs) for maintenance. Many different KTUs are provided, and each one has a specific function to perform; that is, it provides the relay apparatus needed to furnish the desired features in the key system. Each unit has a coded number which identifies the feature provided by that particular unit. Units may be combined, as required, for each installation. Individual units that are assembled and wired at the factory—and are then combined, interconnected, and prepared for connection to the cable—are known as package units. The trend is to order packaged key telephone systems. Since many varied services can be requested, the packages are available in a variety of sizes and features. Thus, we can have flexibility. One package unit is coded as the 200G series. It includes the units that provide pickup and hold features on four to nine central office lines, or the pickup and hold features on four to seven lines with a nine-station dial selective intercommunicating circuit. Audible signaling is provided by an electromechanical interrupter, and visual signaling is done with flashing and winking lamps. Also, a manual intercom circuit is included with the package unit. In addition, the package includes a 75-pair inside wiring cable that is terminated at the terminal plate assembly and the KTUs.

1-16. Note: The full number for a package would be 200G7DC. The 7 discloses the number of central office or PBX lines. The D identifies it as having a nine-station dial selective intercommunicating circuit, and the C denotes that the cable and cable terminal are wired to the unit.

1-17. Other package units were developed

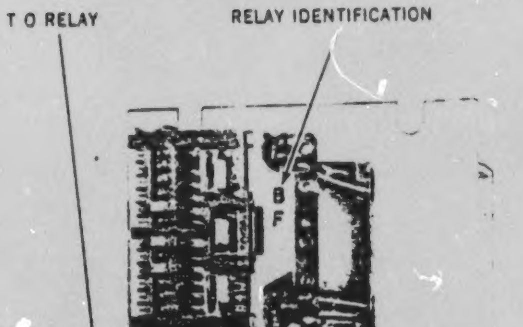


Figure 8. 232B interrupter and control unit.

before the 200G series package, and package units are being or have been developed to replace them and the 200G series. For example, a 300 series package is replacing the 200G series. You must realize that you can be responsible for obtaining, installing, and maintaining the components of any of these packages of the complete package unit.

1-18. We know, then, that individual KTUs are combined to make a package. You will see differences in every type of KTU. Since each type serves a specific function, we will not illustrate all KTUs that provide this service, but only one or two. As a result, you will gain some familiarity with key equipment.

(1) Central office or PBX line unit. This KTU provides equipment for one line. It consists of connecting terminals, relays, rectifying devices, capacitors, and resistive devices (resistors, thermistors, or varistors) (fig. 5) which provide pickup, hold, power failure, and visual supervision on central office or PBX lines. NOTE: Although the KTUs may be manufactured by two or more manufacturers, when these KTUs have the same number, they also have identical circuits and identical connections. Therefore, any unit can replace another having the same number. It is probable, though, that the circuit components are not interchangeable even though the key unit is.

(2) Combined CO or PBX line unit. The apparatus of this KTU includes equipment for more than one line. The exact number of lines is dependent on the particular unit. The components are exactly like those of the 202D, but multiplied. The 230B KTU shown in figure 6 provides four lines identical to the 202D shown in figure 5.

(3) Interrupter and control unit. This KTU (fig. 7) furnishes intermittent ringing, time-out, and flashing and winking lamp circuit features for the key system. Figure 8 shows a 232B unit which is used in conjunction with a 230B, or other multiline units, such as the 239 KTU which provides 9 CO lines.

(4) Dial selective intercom (207C). Selective signaling for up to nine (single-digit) stations connected for intercom is provided by this KTU, but only one common talk link, however. Figure 9 shows the 207C KTU. (Note the rotary stepping switch which enables you to make the selections.)

(5) Common equipment circuit. This KTU provides common audible signal control on incoming calls and battery feed and noise suppression for a manual intercom circuit.

(6) Power unit. A variety of voltages are provided by the various power units available. For example, two different dc supplies are required for relays and transmission. Three separate ac outputs are necessary for bells, buzzers, and lamps. The power unit needed for a particular system must be selected from Bell System Practices or TO 31W2-10-12. The many different type units make it impractical for us to discuss individual units at this time.

1-19. It is apparent from the illustrated KTUs that all associated units appear very similar. To illustrate, the 202D, 230B, 232B, and the 207C have the same type of chassis, the relays appear to be the same, the capacitors are likewise comparable, and the mounting hole spacing is identical. The units have to be alike regardless of the manufacturer because each unit is installed on the same mounting frame (apparatus mounting). Widths vary according to unit. We have discussed a few KTUs and a sample package. However, there are many variations in key systems. You must determine the

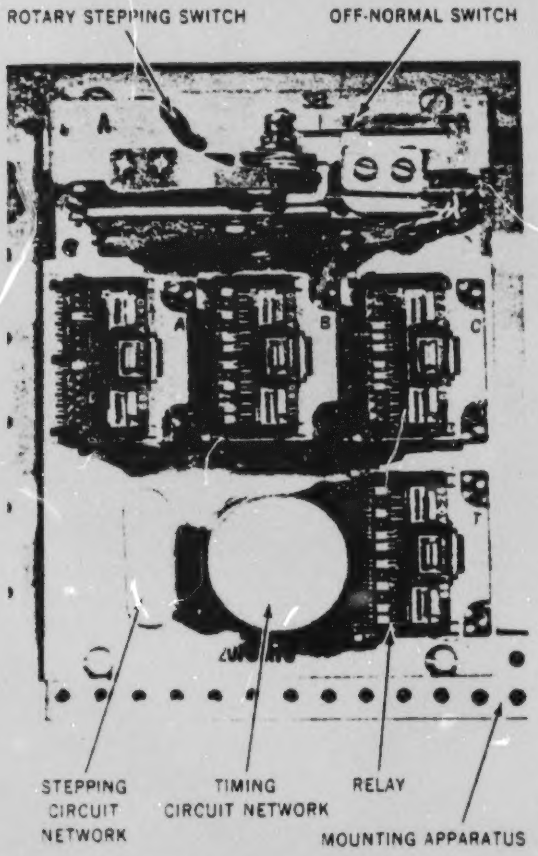


Figure 9. 207C dial selective intercom unit.

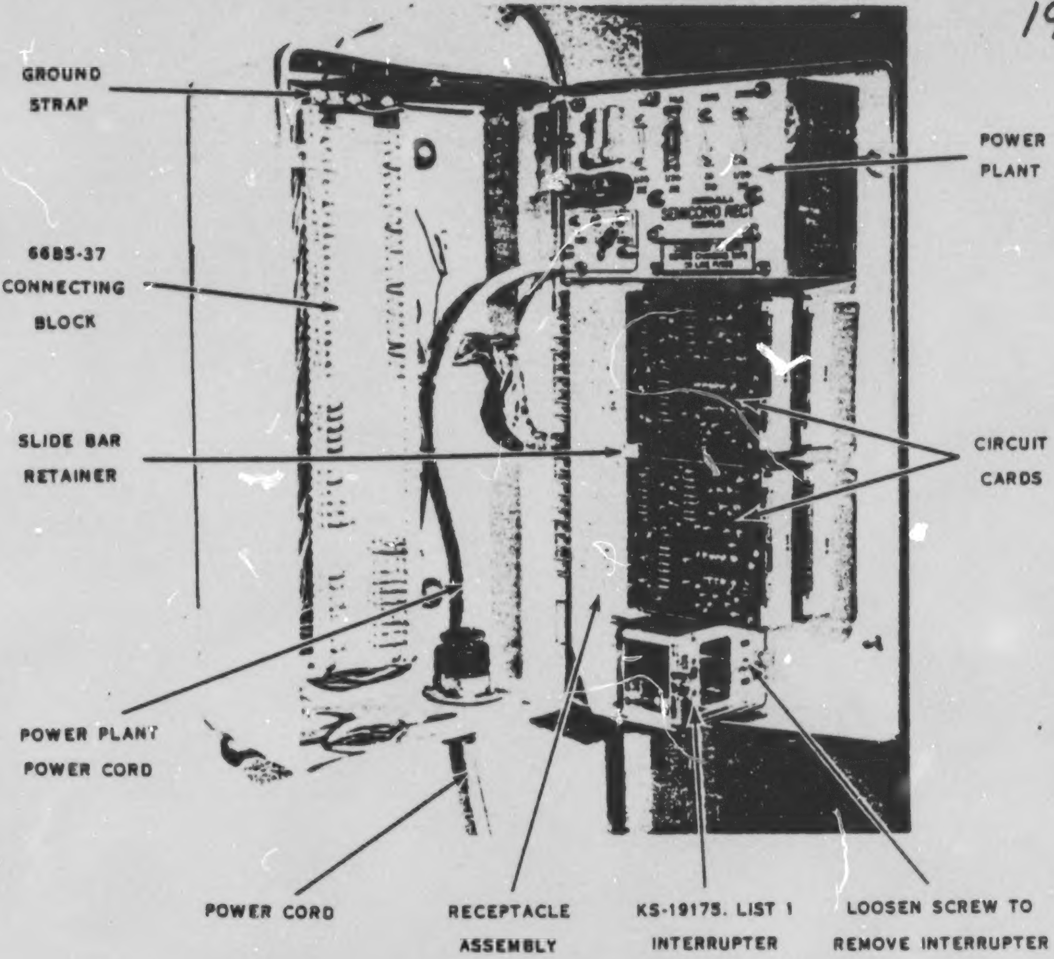

GROUND STRAP
66B5-37 CONNECTING BLOCK
SLIDE BAR RETAINER
POWER PLANT POWER CORD
POWER CORD
RECEPTACLE ASSEMBLY
KS-19175, LIST 1 INTERRUPTER
LOOSEN SCREW TO REMOVE INTERRUPTER
CIRCUIT CARDS
POWER PLANT

Figure 10. 551A key service unit.

subscriber's needs and select the appropriate equipment for each individual installation.

1-20. Type 1A2 Key System. The 1A2 system provides the same functions as did the 1A1 system. You can also order dial intercom as a unit of the package; 1A2 packaged units are referred to as "key service units" (KSUs). The major advantages that a 1A2 package has over the earlier package is its miniature size and its simplicity when you are restoring a unit to operation. The 1A2 line unit (400D) is approximately 4 inches high and 1 inch wide. In the same manner, the KTUs used in association with the 400D are miniaturized. The line circuits are printed on plug-in cards and use transistors and miniature relays. Hence, the card is easily removed and replaced during a troubleshooting procedure. Although the circuits and equipment are new, you can still use the same key telephones.

1-21. The 1A2 key telephone system (KTS) features various combinations of prewired systems available in KSUs and panels. These packages permit a wide latitude in installation flexibility. Some packages are available with interrupters, power units, connecting blocks, and floorstands. KSUs are designed primarily for small-to-medium size 1A2 KTS installations; panels are designed for large or centralized installations. Figure 10 shows a KSU that provides 4 CO lines.

1-22. One of the most popular KSUs is the 513A3, which provides 8 CO lines. This system is sometimes expanded to 16 lines by the addition of a 514, then referred to as a 515 KSU. To provide intercom, it is necessary to sacrifice one CO line. After determining the specific needs of a subscriber, refer to TO 31W2-10-12 for the appropriate package or panel. Chart 1 shows 1A2 KTUs and their

CHART 1

ARRANGEMENT of 400 SERIES KTUs IN 513, 514, AND 515 TYPE KSUs

KTU	SIZE (IN)	PINS	SERVICE FUNCTION	515 KSU															
				513 KSU								514 KSU							
				J1 40 PIN	J2 40 PIN	J3 20 PIN	J4 20 PIN	J5 20 PIN	J6 20 PIN	J7 40 PIN	J8 40 PIN	J11 40 PIN	J12 40 PIN	J13 40 PIN	J14 40 PIN	J15 20 PIN	J16 20 PIN	J17 20 PIN	J18 20 PIN
400D	4	18	CO PBX Line Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
400E	4	18	CO PBX Line Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
401A	4	18	Manual Intercom Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
404A	4	18	Diode Matrix	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚	⁚
407B	8	80	Dial Intercom 10-Code Ckt	●		†	†	†	†	†	†	†	†	†	†	†	†	†	†
413A	4	18	Aux Ring-Up Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
414A	4	20	Ringdown Tie Line Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
415A	4	18	Auto Tie Line Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
416A	4	20	Station Tie Line Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
417A	4	40	Add-On Conf Ckt	†	†	†	†	†	†	●	●	¶	●	¶	●	†	†	†	†
418A	4	20	Short Range Tie Line Ckt	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
419A	8	80	Auto Ringdown Tie Line Ckt	●		†	†	†	†	†	†	●		●		†	†	†	†
420A	4	18	Dial Intercom Long Line Ckt	†	†	●	●	●	●	●	●	●	●	●	●	●	●	●	●
421A	4	40	Power Failure Transfer Ckt	✱	✱	†	†	†	†	●	●	✱	✱	✱	✱	†	†	†	†
422A (MD) or B	4	40	Dial Intercom Station Busy Ckt	†	†	†	†	†	†	●	●	●	†	●	†	†	†	†	†
423A	4	20	Dial Intercom. Aud Tone. Dial Tone. Busy Tone Ckt	†	†	●	●	●	●	●	●	●	●	●	●	●	●	●	●
424A	8	80	Dial Intercom. 19-Code Ckt	●		†	†	†	†	†	†	†	†	†	†	†	†	†	†
425A (MD) or B	8	80	Dial Intercom Flashing Lamp Ckt	†	†	†	†	†	†	†	†	●		●		†	†	†	†
426A and 427B Series 4 or 427C	8	80	TOUCH-TONE Adapter Ckt	†	†	†	†	†	†	†	†	●		†	†	†	†	†	†
	8	80	TOUCH-TONE Adapter Ckt	†	†	†	†	†	†	†	†	†	†	●		†	†	†	†
428A	4	40	Multiline Exclusion Ckt	§	§	§	§	§	§	●	●	●	§	●	§		§	§	§
429A	4	40	Sup Hold Detector Ckt	†	†	†	†	†	†	●	●	†	†	†	†	†	†	†	†
430A	4	20	Flutter Generator	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

● Usable in indicated connector

✱ Restricted to transfer of one station ringer

† Not usable

⁚ Partial use (4 X 3)

§ One circuit only

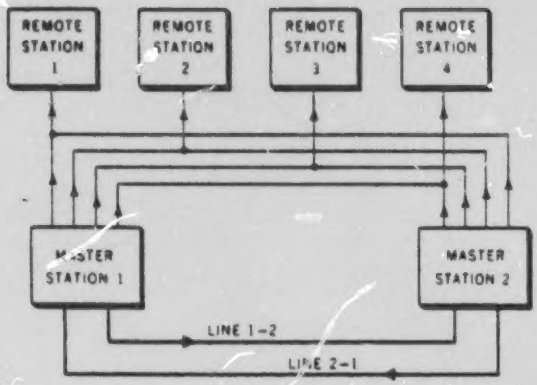
¶ Spare terminals for 13 leads required on connecting block

HL—066

function. This chart also shows arrangement of KTUs within the 513, 514, and 515 KSUs mentioned earlier. The majority of 1A2 key systems installed to date could be built from chart 1; however, as we stated earlier, it may be necessary to consult TO 31W2-10-12.

1-23. 6A Key Telephone System. Although the 6A key system is complete within itself, it is used with 1A1 to provide intercom only. The most commonly used 6A is manufactured by Western Electric, however, Auto Electric Company makes a comparable system which they call 16A. The units cannot be intermixed. Stromberg-Carlson's SC6A provides the same services and will readily intermix with 6A.

1-24. The features and capabilities will differ from system to system depending upon the subscriber's needs. However, we may describe the average 6A system as being an intercommunications system, used with 1A1 or 1A2, equipped to provide 2 private talks links, selective signaling for 18-station (Max 36), camp-on control, and visual supervision. The following KTUs would be required to make up this "average" system:


REMOTE STATION 1
REMOTE STATION 2
REMOTE STATION 3
REMOTE STATION 4
MASTER STATION 1
MASTER STATION 2
LINE 1-2
LINE 2-1

NOTE ARROWS INDICATE DIRECTION OF SIGNALING
SIGNALING INITIATED BY MASTER STATIONS ONLY

Figure 11. Typical intercommunications system.

- 222A - 2 talk links with common equipment and 9 Sta
- 223A - 3 additional station CKT (3 required)
- 207C - Dial selective signaling circuit (Max 9 Sta)
- 216A - Transfer unit (expands 207C from 9 to 18 Sta)
- 224A - Camp-on control
- 217A - Preset conference

Many additional add-on features are available such as add-on conference, long-line circuit, etc., which we do not have time to discuss. TO 31W2-10-12 decribes these units in detail.

1-25. The 6A system comes prewired for 18 stations but can be expanded to a maximum of 36 stations. The most frequently used package is the 200H18DC, which we referred to earlier as an "average" system. Since this 6A system is standard, you will do little or no "building" of 6A systems. Consequently, we will not go into detail on possible arrangements. The 6A system has been largely responsible for the decreasing popularity of intercommunications (squawk box) systems, which we discuss next.

2. Intercommunications

2-1. An intercommunications system may

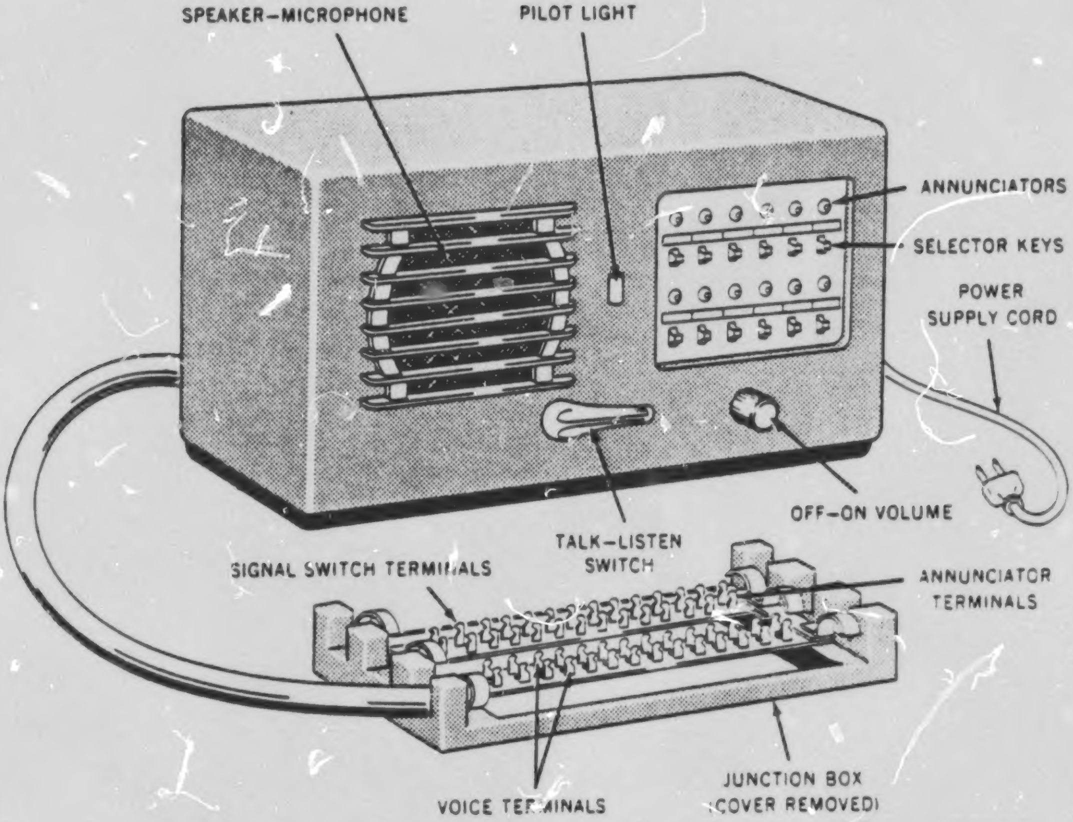

SPEAKER-MICROPHONE
PILOT LIGHT
ANNUNCIATORS
SELECTOR KEYS
POWER SUPPLY CORD
OFF-ON VOLUME
TALK-LISTEN SWITCH
SIGNAL SWITCH TERMINALS
ANNUNCIATOR TERMINALS
JUNCTION BOX (COVER REMOVED)
VOICE TERMINALS

Figure 12. Master station LS-125A/F1.

be described as a network of master stations and remote stations tied together by cable or wire for the purpose of interoffice communications. Figure 11 is a block diagram of a typical intercommunications system. As you can see, the stations in this figure are connected to permit the two master stations to converse with each other, and either master station to talk with all remote stations individually or simultaneously. The remote stations cannot converse with each other.

2-8. Almost any interoffice communication requirement can be satisfied with intercommunications equipment if you know the operating capability of the sets and understand the interconnecting schemes. The master stations can be used to select, call, and talk to a number of master stations and remote stations, individually or in combinations, if they are connected in the same system. These master stations are central switching points and furnish their own power as well as power for the remote stations. The remote stations (often called slave stations) allow the reception and transmission of voice signals; and, in some cases, operate a visual signaling device at the master station. The equipment normally operates on alternating current; however, you can get equipment that operates on direct current. It is quite possible that the units in use at your base were locally purchased. Thus, their connections and features will vary from what we show as a representative unit (fig. 12). Likewise, if more than one locally purchased unit is being used, you may find differences in them. Consequently, it is advisable first to learn the operating and connecting principles of a system. Then you should analyze the instructions, schematics, and structure of those for which you are responsible.

CHAPTER 2

Operating Principles of Key System Equipment

YEARS AGO a telephone caller originated a call by turning a generator handle, lifting a handset, and requesting an operator to make the connection. After the call was completed, the originating party was required to re-ring the operator. Analysis of this calling procedure revealed that time and effort would be saved if the lifted handset would automatically indicate to the operator a need for assistance, and the restored handset would likewise identify the call as being completed. The dial and additional improvements further increased the efficiency of the telephone system.

2. We learned that a key system provides greater organizational efficiency. This would not be true if the personnel were unable to operate the equipment. The operating procedures are not difficult, however, because they are familiar actions. For instance, you lift a telephone handset as one of the initial actions. In addition, you press a pushbutton. These two steps are used regardless of the key system. Dialing a number may be a subsequent procedure. Of course, this last act should offer no challenge to you either.

3. Knowing the operating procedures is not enough, though. If you are to be considered an efficient repairman, you must know the principles that permit the equipment to function. Hence, you must understand what is happening when you lift the handset and depress each pushbutton. Some results are also familiar because we described similar effects in the earlier volumes. For example, in a previous volume was a description of the results of your removing the telephone handset from its cradle switch, thus lighting a busy lamp. The method by which the lamp is lighted can vary, however. Of course, it lights because an electric circuit is completed. In this chapter we interpret schematics to find out how electrical circuits in a telephone system are completed.

3. Schematics and Their Interpretation

3-1. Since the 230B is the most common CO line unit, we use it for our discussion. This same circuit explanation will apply to the 202D, 238A, 239A KTUs.

3-2. Since the operation of the 230B KTU controls the operation of the 232B; and the operation of the 232B controls the audible and visual signals at the telephone through the 230B; it is necessary that we discuss the two units at the same time.

3-3. To trace a circuit on a schematic the circuit must be complete, from one side of the power supply to the other. The positive side of the battery supply is shown on these drawings as GROUND; the negative side of the battery supply is shown as BATTERY. Any circuit tracing must start at one and stop at the other.

3-4. In some of the circuits to be traced and discussed, the only known point from which to start is the middle of the circuit. In this case you trace one way, or the other, to find either battery or ground. Having found either battery or ground, the circuit must be retraced to the starting point and on, until the other side of the power supply is reached. We are establishing continuity only; current flow will be considered as being from negative to positive, when continuity has been established. Immediately following the circuit descriptions, you will find sequence charts and operational sketches. You may, while reading the circuit description, refer to the operational sketches and sequence charts for verification.

3-5. In the following paragraphs, the circuits controlling each relay, and the circuits controlled by each relay, of both the 230B and 232B KTUs, will be discussed and analyzed. In the discussion of the circuits, each contact will be covered, in turn, from bottom to top, as they are drawn in the schematic of foldout 1.

4. 1A1 Key System Operation

4-1. Foldout 1 shows the circuits of the 230B KTU and the wiring connections to a 564HL telephone. All of the circuits to be discussed here may be traced completely on this drawing. The discussion will be on only one line circuit of the 230B but there are four line circuits in parallel. What applies to one line circuit applies to each of the others. The same circuits exist in the 202D KTU, so these descriptions also apply to the 202D. Except for very minor differences, the same symbols and descriptions also apply to the 230A, 232A, and 202C KTUs.

4-2. With the 230B KTU it is possible to have either grounded ringing, or metallic ringing. However, with this type system the usual policy is to use metallic ringing. Therefore, our discussion here will use metallic ringing. Refer to foldout 1 while reading the rest of this analysis on the 230B and 232B KTUs.

4-3. Incoming Call. Ringing current (20-cycle ac) is applied to the ring side of the line on an incoming call (terminal 8 of the 230B KTU); ac current flows through the normally closed contacts B4 of the AH relay, capacitor R, thermistor R, and the secondary winding of the R relay to the tip side of the line on one half of the cycle. During the other half cycle, current flow is from the tip side of the line (terminal 7) through diode R over the same path as previously described, to the ring side of the line. Contacts B4 of the AH relay and B9 of the A relay together establish a path for current that bypasses the H relay and prevents the establishment of a false hold condition, which might occur when a number of ringers are bridged across the station side of the line. The 317A varistor R1 protects the 400E diode and thermistor R from transient currents.

4-4. Thermistor R has a nominal resistance of about 50,000 ohms. This prevents false operation of relay R on disconnects or from transient currents. Ringing current increases the temperature of the thermistor, which reduces the resistance to about 3000 ohms in about one-half second.

4-5. *R relay operation.* The one-half cycle of ringing current operates the R relay closing M4, M6, M8, and M10 contacts.

- M4. The closing of contacts M4 places ground on the LK lead, through the secondary winding of the R relay. The LK lead may be traced from contacts 4 to contacts 5 of the AH relay, to terminal 22, to the 232B KTU, terminal 38, through the bimetal contacts 1 and 2 to 20 volts battery. This circuit locks up the R relay under the control of the AH relay, the LK lead and the bimetal contacts of the 232B KTU.

- M6. The closing of contacts M6 operates the audible signal. Trace from the stationary contacts of M6, to the left, to terminal 10, out through the audible signal, back to terminal 25, which is strapped to terminal 30 and the ground side of the audible signal power supply. Retrace this circuit back through terminals 30, 25, the audible signal and terminal 10, through the made contacts M6, then to terminal 9 of the 230B KTU and out to option "X." This wiring will go to terminal 21 of the 232B KTU to pins 7 of the interrupter plug, to contacts 2 of the interrupter, to pins 4 of the plug, to terminal 29 and to the "hot" side of the audible signal circuit, under the control of the interrupter at contacts 2.

- M8. The closing of contacts M8 of the R relay will actually complete two separate circuits, one through the heater on the TO relay and the other through the windings of the ST relay of the 232B KTU. Trace the first circuit from ground at M8 of the R relay, to terminal 23 of the 230B, out on the TO lead to terminal 36 of the 232B KTU, through the 112-ohm heater resistor, through the closed contacts 3 and 2 of the TO relay, to 20 volts battery. Current flow in this circuit will cause the 112-ohm resistor to become hot and this heat will, in a period of about 30 seconds, cause the bimetal contacts in the R relay lock circuit to open, releasing the R relay, if the call has not been answered in the meantime. Now, to trace the second circuit involved by the closing of contacts M8 of the R relay, trace through the same terminals and TO lead to terminal 36 of the 232B KTU, through the strap to terminal 35 and through the windings of the ST relay to 20 volts battery. This will operate the ST relay. The results of the operation of the ST relay will be covered in a later paragraph.

- M10. The closing of contacts M10 completes the circuit to light the lamps on the telephone. It is recommended that this circuit be traced from the stationary contact of M10, up to contacts EBM2 of the AH relay, over the contacts EMB8 of the A relay, to terminal 15 and 5, out of the L or lamp lead to the telephone, through the lamp, back to the LG or lamp ground lead to terminal 6 and lamp power supply ground. Having found ground, retrace the circuit to contacts M10 of the R relay. From these now closed contacts, trace to terminal 19 of the 230B KTU, out on the LF lead to terminal 1 of the 232B KTU, through the strap to terminal 2, to pins 10 of the interrupter plug, to contact 4 of the interrupter, to pins 17 of the plug, to terminal 10 of the 232B KTU to the "hot" side of the lamp power supply.

4-6. If you will review the circuits we have just traced, you will find that we have the R relay locked up, the audible signal operating and the lamp in the telephone *lit*, all under control of the 232B KTU. If the call is not answered in the 30 seconds that it takes for the bimetal contacts at the TO relay to operate, the R relay will release and everything will go back to normal.

4-7. *ST relay*. Now, return to the ST relay. The operation of the ST relay will close contacts 1 and 2 both above and below the relay. They are in parallel and are connected directly to terminal 26 and the "hot" side of the 10 volts, 60-cps ac of the power supply. (Until the entire CDC is revised, cps will be used for Hertz.) From these now closed contacts, trace to pins 2 of the plug, through the motor (M) to pins 1 of the plug to terminal 27 and the ground side of 10 volts ac. This will start the interrupter motor operating. To show what the operation of the motor will do, each set of contacts will be described in detail, from contact 1 down to contact 8. All contacts are shown on the drawing in their starting or normal position.

4-8. *Interrupter operations.*

- Contact 1. This contact closes approximately 0.25 second after the initial operation of the ST relay. When closed, it completes an operating path for the interrupter motor M. This will cause the motor to continue to operate when the ST relay is released until it returns to its normal or starting position. In other words, the motor always returns to the point where all contacts are in the position shown in the drawing.
- Contact 2. This contact will furnish an interrupted signal voltage to operate any audible signal connected to line circuits of the 230B KTU that have the R relay operated.

NOTE: One unusual feature of the audible signal obtained under the control of the interrupter is that the signal does not follow the interruption frequency of the central office ringing signal but is completely independent of the central office after the motor has started.

- Contacts 4 and 5. These two sets of contacts control the flashing lamps that indicate an incoming call. They operate at a frequency of approximately 0.5 second on and 0.5 second off and will flash the lights connected to the line circuit that has the R relay operated in the 230B KTU. Each contact, 4 and 5, is actually a pair of contacts, each capable of carrying a current of 2.5 amperes. With four contacts, this gives a total lamp load of approximately 10 amperes. This gives enough capacity to care for the entire needs of all lamp circuits in a 6A key system with up to 36 stations. The lamp circuit traced in the preceding paragraphs is connected to contact 4A, so any lamps connected to that particular R relay are now flashing.
- Contacts 7 and 8. These contacts control the station lamp wink circuit indicating a hold condition on the line. The frequency of operation is approximately 0.475 second on and approximately 0.025 second off. The contacts are arranged like contacts 4 and 5 with two actual contacts each, rated at about 2.5 amperes per contact.

4-9. **Answering an Incoming Call.** To answer an incoming call at a key telephone, the button with the flashing light is depressed and the handset picked up. The immediate noticeable effect is the stopping of the flashing light and the audible signal, and you find that you can answer the call and carry on the conversation. The light under the button is burning steadily now. But in order to know just what has happened in the system, it will be necessary to trace the circuits and operations of the various relays.

(1) A relay operation. A chain of operations is started by the A-A1 or control circuit. The hookswitch of the telephone completes this circuit, which can be traced from terminal 4 of the 230B KTU (which is connected to ground) through the A1 lead to the telephone, through the hookswitch and back to the KTU on the A lead to terminal 3, then through the coil of the A relay to 20 volts battery. This operates the A relay, which breaks contact B9 and lower contacts EBM11, 8, and 12; it simultaneously makes contact M10 and upper contacts EBM11, 8, and 12.

- EBM11. The making of the upper contact of EBM11 makes connection to 20 volts battery and will operate the AH relay.
- M10. M10 contact is not used under normal conditions.
- EBM8. The making of the upper contact of EBM8 connects lamp battery directly from

terminal 29 (or 28) to the lamp in the telephone, causing it to burn steadily. At the same time, the breaking of the lower contacts opens the circuit that was flashing the lamp.

- B9. The breaking of contact B9 opens the circuit that allowed the ring side of the line to bypass the H relay under power failure conditions.
- EBM12. The breaking of the lower contacts EBM12 opens a circuit that would carry the "ring" of the line through the H relay, while the now closed upper contacts again provide a bypass around the H relay.

NOTE: The above operation of the A relay has operated the AH relay, stopped the flashing lights but turned them on steady, and *changed* the bypass path around the H relay for the "ring" of the line.

(2) AH relay. The operation of the AH relay will open contact B5, close contact M1, open the lower and close the upper contacts EBM2, and open the upper contacts EBM2, and open contact B4.

- B5. Breaking contact B5 opens the LK or lock circuit for the R relay. This will allow the R relay to release and open the lamp flashing circuit, open the TO lead, which will stop the heater of thy time-out circuit, and release the ST relay in the 232B KTU, allowing the motor to stop when it returns to its normal position.
- M1. Closing of contact M1 will operate the TO relay of the 232B KTU. This circuit may be traced from the ground at contact M1 to terminal 24, out on the CO lead to terminal 37 of the 232B, through the coil of the TO relay to 20 volts battery. The operation of the TO relay places another open in the TO lead. As the AH relay is in each line circuit of the system, then whenever there is a line in use in the system, the TO relay will be operated and the heater circuit will be open. This stops all time-out operation when the system is in use.
- EBM2. The operation of EBM2 contact opens the lamp flashing circuit and at the same time makes ready a circuit for the lamp wink. As the lamp wink circuit is used only when a line is being held, this circuit will be discussed then.
- B4. The opening of the B4 contacts removes the R relay and its operating circuit from the line so there will be no transmission losses through it.

4-10. *Talking circuit.* With the A and the AH relays operated as described above, there is a direct talking path through the unit, under the control of the A relay, which is in turn controlled by the A and A1 circuit and the telephone hookswitch. This talking circuit may be traced, starting at the tip of the incoming line at terminal 7, directly to terminal 1, through the cord and telephone, back on the ring of the cord to terminal 2, through the now closed upper contacts EBM12 of the A relay to terminal 8 and the ring side of the incoming line.

4-11. Holding. If it is desired to hold a line while another line is in use, the HOLD button on the telephone is pressed down. This action will open the A and A1 (control) circuit at the telephone and release the A relay. The handset is still "off hook" so the T & R is still complete. The release of the A relay will allow all its contacts to return to their normal position. The release of contacts EBM12 removes the bypass around the H relay. Current from the central office now passes through the H relay and will operate.

(1) H relay operation. The operation of the H relay will close its contacts M8, M6, and M4.

- M8. The closing of contact M8 will complete a circuit from the tip of the line through the coil of the H relay to the ring of the line, through the lower, now closed, contact EBM12 of the A relay. The mechanical release of the line button on the telephone set by the hold button removes the telephone from the line and the H relay is now locked across the line by its own contacts. This puts a 180-ohm resistance short on the line and holds up the central office equipment.
- M6. The closing of the M6 contacts picks up the 20-volt battery and through the now closed lower contact EBM11 of the A relay holds the AH relay operated. The AH relay is slow-release and remains operated during the time between the release of the A relay and the operation of the H relay.
- M4. The closing of the M4 contact completes a circuit from the ground at M4 to terminal 21, out on the HA lead to terminal 35 of the 232B KTU and then through the coil of the ST relay to battery. This operates the ST relay and starts the interrupter motor.

(2) Lamps. The lamp for the held line will now "wink." This is done under the control of the AH relay and the interrupter motor of the 232B KTU through the LW lead and circuit. To trace the LW or lamp wink circuit, start at terminal 6 of the 230B KTU, which is lamp ground (LG), out through the LG lead to the telephone, through the lamp and back to the KTU on the L lead to terminal 5, through the now made lower contacts of

EBM8 of the A relay, through operated upper contacts EBM2 of the AH relay, to terminal 20, out on the LW lead to terminal 11 of the 232B KTU to plug pins 12, contact 7B, to pins 14, to terminal 19, to terminal 9 and lamp battery. The winking will continue until the line is again picked up.

NOTE: Placing a call is the same as answering except the "R" relay is not operated. Therefore, we will not make an analysis of placing a call.

4-12. **Power Failure.** Operation of a telephone in the system for outgoing calls, during a period of power failure at the user's location, will seemingly be normal except that there will be no lights on the telephone. This circuit may be traced, with the circuit in its normal, unoperated condition, as it is drawn. Trace from terminal 7 of the 230B KTU, through the KTU of the telephone and back to terminal 2 of the KTU, through the normally closed contacts B9 of the A relay and B4 of the AH relay, and to the ring side of the line. During power failure conditions, no incoming calls will be received unless a ringer has been bridged on the line.

4-13. **Dial Selective Intercom.** The 207C KTU is a nine-station dial selective intercommunication unit. It will select and signal any one of nine stations by means of a step switch, controlled by the dial at the telephone. It has but one talking circuit that is common to all stations; therefore, only one conversation is possible at one time. The 207C is completely independent in operation from any other unit in the 1A1 key system. (In later Bell System Practices, the 207C is frequently referred to as "Selector only 6A equipment." Here we are including it as a part of the 1A1 key system, but it should be thought of as a completely independent part of that system.)

4-14. The circuits of the 207C KTU are shown in foldout 2. In our discussion here, we use only that part of the complete circuitry that is needed for the nine-station system. In the following paragraphs we explain in detail how the circuits and relays operate. Follow the circuits through the schematic as you read; take your time and become completely familiar with the circuit and its operation.

NOTE: Remember, there is only one talk circuit and all telephones are connected across ring and tip as on a party line. Ring and tip connections are shown at terminals 1B and 2B.

4-15. All battery and other power must be brought to the unit, either by strapping it from other KTUs in the system or direct from the power unit. On the schematic shown in foldout 2 the dc voltages necessary are shown connected to terminals at the lower left-hand side of the drawing. Talk or "A" battery is connected to 9B and "A" ground to terminal 10B. Signal or "B" battery is connected to terminal 19B and "B" ground to terminal 20B. All grounds are to be strapped together at the powerplant.

4-16. Lamp ground and ringer or buzzer supply ground are shown connected to terminals 30B and 40B, respectively, on the right-hand side of the drawing. Lamp power is shown connected to terminal 29B and ringing power to 39B, both on the left-hand side of the drawing. Lamp supply is usually 10-volt, 60-cycle ac. Ringing power could be 18 volts ac for buzzers or 105 volts ac for regular bells. We will assume that regular bells are to be used.

4-17. In the previous KTUs that we have discussed, each relay operated more or less independently of the others. In the 207C KTU there is much more interdependence because no relay is able to do very much by itself. It requires all of them working together to do the job.

4-18. We are going to assume that it is desired to place a call to station 9 from some other station. To seize the line, the handset is picked up, allowing the hookswitch to close, and completing ring and tip through the telephone. Battery will be present, so sidetone will be heard. (There is no dial tone.) The circuit completed by lifting the handset may be traced, starting from A battery at terminal 9B, through one winding of the A relay, to terminal 2B, out on the ring of the line, through the telephone, back on the tip of the line to terminal 1B, to the other winding of the A relay, and through that winding to ground at terminal 10B. Current flowing through the two windings of the A relay will cause it to operate, closing its contact M6, and at the same time opening contact B10. The closing of contact M6 places a ground on a lead that goes directly to the windings of the B relay and to battery and causes the B relay to operate. This same ground is also carried on a parallel circuit through the 47-ohm resistor to the A2 capacitor (25MF) of the KS-16171 network. This will equalize the charge on this capacitor as the other plate is connected to battery. The ground plate is charged positive and the battery plate is charged negative; the two charges are equal, so no action takes place at this time.

(1) B relay. The B relay will operate all of the contacts shown above the relay, closing

the ones shown open and opening ones shown closed. Each contact will be covered if it serves a purpose.

- Contact M2. This contact makes ready a circuit to furnish ringing power through the selector to ring the telephone selected.
- Contact M4. This contact makes ready a circuit to release the step switch.
- Contact M1. Completes the circuit to light the busy lamp on the telephone.
- Contact EMB8. Makes ready a circuit to feed the pulses from the A relay to the selector when the dial is operated; also makes ready a circuit that will operate the C relay on the first of these dial pulses. Digit 1 is not used, only 2 through 0 may be selected.

4-19. We have seized the unit and lit the lamp at all stations. Line seizure is complete. The next step in placing a call is the dialing of the digit assigned to the telephone we wish to call. We are attempting to call station number 9, so we dial the digit 9. The pulse springs of the telephone dial will open the telephone circuit nine times during the operation of the dial. The A relay of the 207C will follow those pulses and release and reoperate nine times. With the first dial pulse, the A relay will release, opening contact M6 and closing contact B10.

4-20. The removal of the ground at contact M6 of the A relay opens the operating circuit of the B relay. This would normally cause the B relay to release, but the capacitor A2 of the KS-16171 network was in a balanced condition as long as the ground was connected at contact M6. With the opening of the contact M6, this is no longer true. The capacitor is now connected so that the side that was positive is now connected through the windings of the B relay to negative battery. Therefore, the plate that was positively charged will become negative. This discharge of the capacitor will cause enough current flow through the 47-ohm resistor and the B relay windings to hold it operated during the period of time that its operating circuit is opened by the release of the A relay. This slow release of the B relay will cause all of the circuits controlled by the B relay to remain in the condition described under operation of the B relay. The closing of contact B10 of the A relay will complete a circuit from the ground at B10 of the A relay through the closed upper contacts EMB8 of the B relay and up to the rotary magnet to step the selector one time. At the same time a parallel circuit from contact EMB8 of the B relay will cause the C relay to operate.

(2) C relay. Contact M6 closes a completely local circuit which will make the C relay slow to release. When the C relay operating circuit is broken by the action of the A relay, an inductive kick from the primary winding of the C relay will induce a voltage into the secondary winding, completed through contact M6, which will cause enough current to flow to hold the C relay operated during the dial pulse.

- Contact M4 completes a circuit to operate the T relay.
- Contact B5 will open the circuit supplying 105 volts ringing current for the ringing of the called telephone. Opening the circuit at this time and place prevents false rings.
- Contact B9 places an open in the circuit that will finally release the step switch.

NOTE: The only actual complete operation that took place with the operation of the C relay was the operation of the T relay. But the C relay did take over control of the ringing circuit and of the step switch release circuit.

(3) T relay. The operation of the T relay will operate all of its contacts as shown above it. Only four of these are of any interest to us, the others not even being wired.

- Contact M1. The closing of this contact completes a circuit that at this time is parallel with the operating circuit of the T relay. This circuit will charge capacitor A1 of the KS-16171 network and will later make the T relay very slow to release.
- Contact M2. This contact prepares the ringing circuit for the called telephone; a circuit that is now held open by contact B5 of the C relay.
- Contact EMB6. This contact places the release of the step switch under the final control of the T relay. This circuit is also held open by the C relay, but the T relay will release much slower than the C and so will have final control of the circuit.

(4) ON (OFF-NORMAL SWITCH). This switch, shown at the top right-hand side of the drawing, is mechanically operated and it is held open, as shown, by a pawl on the end of the step switch lever. As soon as the step switch moved from its normal position, the ON switch operated and closed its contacts 1 and 2, and 3 and 4, opening contacts 4 and 5. This switch will remain in this position until the step switch again returns to its normal, at rest, position.

4-21. The other eight pulses of the dial (we are dialing station 9) will cause the A relay to

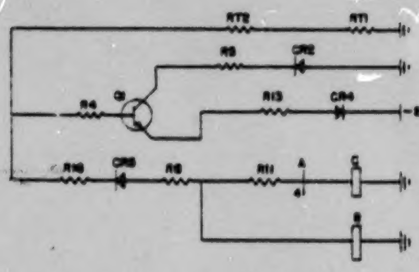


Figure 13. Positive bias for Q1 in ON condition.

release and reoperate in step with the dial. Each release of the A relay will place a ground on the lead that operates the rotary magnet, which will cause the step switch to move one step. At the completion of the nine pulses, the step switch will be on contact 9 and the A relay will again assume its operated position. This will reenergize the B relay, which was held operated by its own slow-to-release circuit, and hold it operated during the rest of the time that the telephone is on the line. The A relay, being operated, opens contact B10 which removes the ground that operated the C relay. The C relay will release, after a slight delay. The release of the C relay will allow its contact M4 to open, and contacts B5, B7, and B9 to close. Contact B5 will complete a circuit that provides a path for 105V ac ringing current from terminal 39B, through contacts M2 of the B relay, through the B5 of the C relay, through M2 of the T relay, to the contacts of the step switch to contact 9 and terminal 19A, out through the R lead to the telephone bell and back from the bell to ring ground at terminal 36B, 37B, 38B, or 40B. This completed circuit will ring the bell at the telephone s long as the step switch stays on contact 9 and T relay stays operated.

4-22. When the C relay released and opened contact M4, the operating circuit for the T relay became open. With this contact open, capacitor A1 of the KS-16171 network is now connected directly across the windings of the T relay, through the 47-ohm resistor and contact M1 of the T relay. This capacitor has a capacitance of 600 MFD and is fully charged. It now begins to discharge through the 47-ohm resistor and the windings of the T relay to keep the relay operated for about [illegible] seconds, during which time the telephone will ring at the station called. When the A1 capacitor can no longer hold the T relay operated, the relay will release and stop the ringing.

4-23. When the T relay releases at the end of the 1½-second time-delay period, it will allow contacts M1, M2, and M4 to open and contact EMB6 to close.

- Contact M1 opens the time-delay circuit for the T relay.
- Contact M2 opens the circuit that was supplying ringing current to the telephone.
- Contact EMB6 closing completes a circuit for the operation of the release magnet. To trace this circuit, start at the ground on contact M6 of the A relay, through the now closed contact M6 to contact M4 of the B relay, now closed, through contact B9 of the C relay, also closed, through contact EMB6 of the T relay, which has just closed, to contacts 1 and 2 of the ON switch, held closed by the step switch, and to the release magnet, to battery. This circuit will operate the release magnet and release the step switch, which, being spring loaded, will return to its normal position. The step switch, returning to its normal position will open the ON switch, opening the release magnet circuit. NOTE: The telephone has been rung one time, for a period of about 1½ seconds. If the party does not answer, it will be necessary to redial the number to ring the bell again.

4-24. Only the A and B relays are now operated. They will continue to be operated until both parties hang up at the end of the conversation.

5. 1A2 Key System Operation

5-1. We saw that the 1A1 key system provided signaling, holding, supervision, and talking features for an organization. The 1A2 key system also provides all these features. However, the circuits consist of devices that differ greatly from those used with the 1A1. Therefore, we think it important that we describe some of the circuit tracing variations.

5-2. Since the 1A2 system is transistorized, we have included operational sketches along with the circuit description. As you read the circuit description, you will find figures 13 through 25 helpful in understanding the individual circuits. You should then locate these circuits on figure 26, which is a complete schematic drawing of the *400D KTU*, the most commonly used CO line unit. We will begin our explanation by analyzing the circuit while idle. In the idle circuit condition, all relays are in the unoperated state, and transistors Q2 and Q3 are off. Q1 is

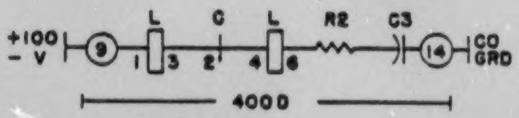


Figure 14. L Relay operate.

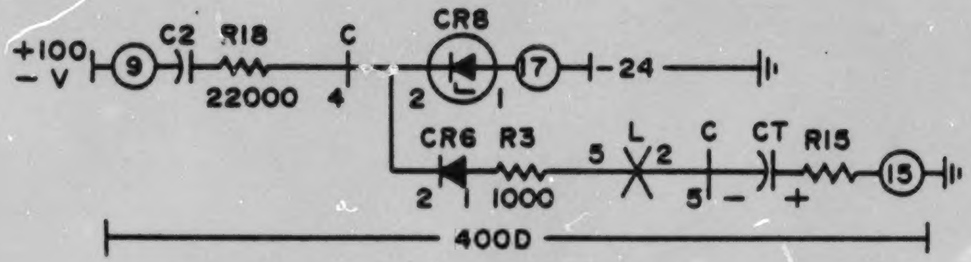


Figure 15. CT charging circuit.

on. ALL TRANSISTORS ARE OF THE NPN TYPE. Since the 400D is the most commonly used CO line unit, we discuss its circuitry in detail. Refer to the operational sketches and figure 26 as you read the circuit description.

5-3. Transistor Q1 is held on by positive current supplied to its base through the resistor network formed by RT1, RT2, R4, R8, R16, R11, and the B and C relay coils. Figure 13 shows this bias circuit.

5-4. Incoming Signal. Ringing voltage is usually applied across the line with the tip side of the line grounded. (The actual circuit operation will be the same if the ringing voltage is applied across the line with the ring side of the line grounded.) Ringing current flows through the series connected primary and secondary of the L relay, resistor R2 and capacitor C3, causing the L relay to operate on each half-cycle of ringing current. Figure 14 shows this circuit. Ringing current also flows through C2 and R18 (C5 and R17 if the ring side of the line is grounded) to terminal 2 of Zener diode CR8.

5-5. The negative (-) side of capacitor CT is normally maintained at about -16 volts. Negative half-cycles of ringing current cause CR8 to conduct in the forward or normal direction so that terminal 2 of CR6 is at about -24.5 volts and the - (negative) side of CT charges toward -24 volts. Figure 15 shows this operation.

5-6. Positive half-cycles of ringing current cause CR8 to break down so that terminal 2 of CR6 is at about 0 volts. The - (negative) side of CT is somewhere between -16 and -18 volts, so CR6 is reverse biased and CT does not charge. However, CT does discharge through the resistor network formed by RT1, RT2, R8, R11, R16, and the B and C relay coils. The charge lost by CT during this positive half-cycle is much less than that gained during the negative half-cycle. These discharge paths are shown in figure 16.

5-7. As the charge lost by CT is much less during the positive half-cycle than the charge built up during the negative half-cycle, the charge on the - side of CT will gradually build up on the ringing current. After about 1/2 second, a sufficient number of cycles of ringing will have been received to charge CT to about -18 volts. This is equal, but opposite to, the base voltage applied to Q1 transistor, and it will stop conducting. When Q1 stops conducting, its collector voltage rises, raising the positive voltage applied to the base of Q2, and Q2 starts conducting. With Q2 conducting, Zener diode CR7 breaks down and Q3 starts conducting, operating the B relay. Figure 17 shows the operation of the B relay. Find these circuits in figure 26. Note: Relay C does not operate at this time since resistor R11 limits the current through its winding to less than its operate value.

5-8. Relay B operated connects ground to the ST lead, the L lead to the LF lead, and the interrupted (option W) or steady (option T) ringing current, or ground (option V) to

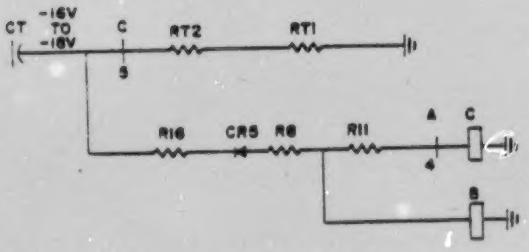


Figure 16. CT discharge path.

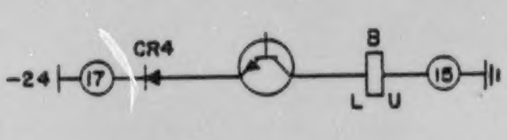


Figure 17. B operate path.

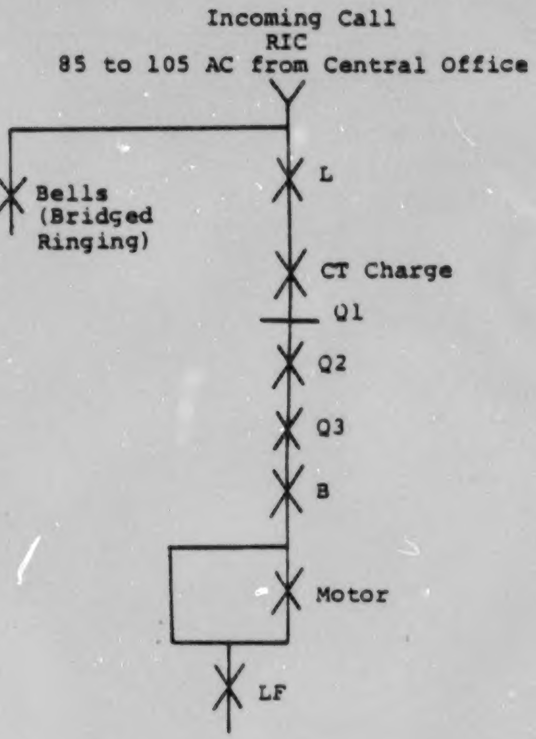


Figure 18. Incoming call.

the RC lead for audible signal control. Transistor Q1 remains off and Q2 and Q3 remain on until the call is answered or timed out. Now, review the sequence in figure 18.

5-9. Time-Out. At the instant Q1 turns off, the voltage at the - side of CT is about - 18 volts. When the B relay operates, the voltage divider formed by resistors R14 and R15 is switched into the circuit, and the voltage at the + side of CT drops from 0 volts to about - 6 volts. Consequently, the - side of CT drops from - 18 to about - 24 volts.

5-10. On subsequent positive half-cycles of ringing, CR6 will be reverse biased as before. Operation of relay B caused terminal 1 of CR5 to be connected to - 24 volts through resistor R8, transistor Q3, and diode CR4. Terminal 2 of CR5 is connected to the base of Q1, which is at about - 24 volts, so CR5 does not conduct.

5-11. The discharge path for CT is thus only through resistors RT1 and RT2 to ground. On negative half-cycles of ringing, CR6 will conduct slightly to restore the charge lost by CT during the previous positive half-cycle. In this way, the charge on CT, which determines the duration of the time-out, remains constant once the circuit has operated, regardless of the duration of the ringing burst.

5-12. When the first burst of ringing has ceased, the - side of CT begins to change towards ground through RT1 and RT2. Transistor Q1 remains off until the voltage at the - end of CT reaches - 18 volts, at which time Q1 turns on and its collector voltage drops. This causes Q2, CR7, and Q3 to turn off and relay B to release, and the circuit is returned to normal. The time required for the B relay to release after a burst of ringing or after a call has been abandoned is approximately 30 seconds.

5-13. Time-Out of Ringup Circuit (Z Option). This arrangement functions in a manner similar to that described above with the exception that RT2 is short circuited. This lowers the resistance through which capacitor CT discharges and results in a shorter time-out.

5-14. On incoming calls where one burst of ringing is received, as with manual ringing from a PBX board, the time-out is approximately 11 seconds. Subsequent bursts of ringing received before the B relay releases will reset the time-out circuit to approximately 10 seconds. Incoming calls, signaled by machine ringing, will time out in approximately 10 seconds after the call is abandoned by the calling party.

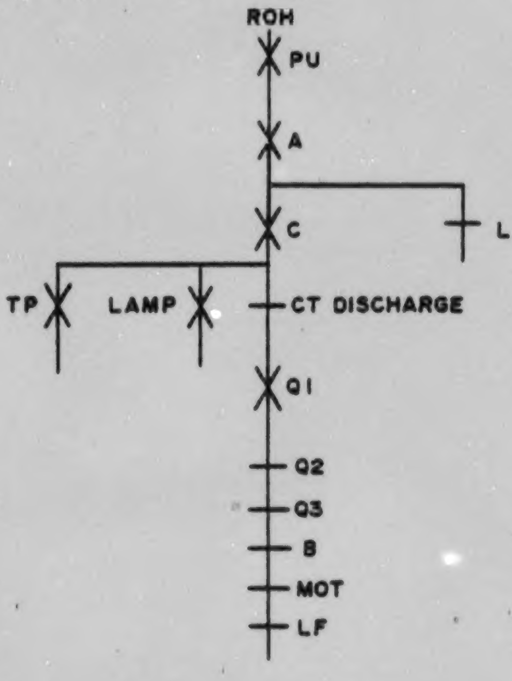


Figure 19. Answering.

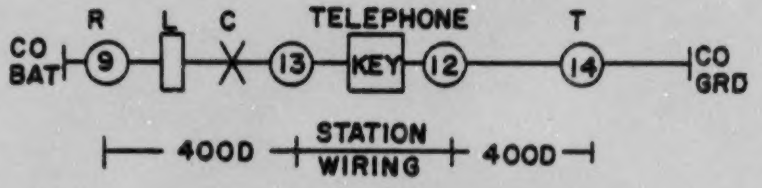


Figure 20. L operate (holding).

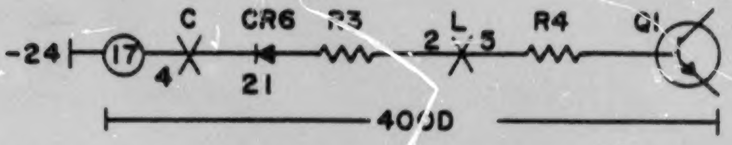


Figure 21. Negative bias on Q1 (holding).

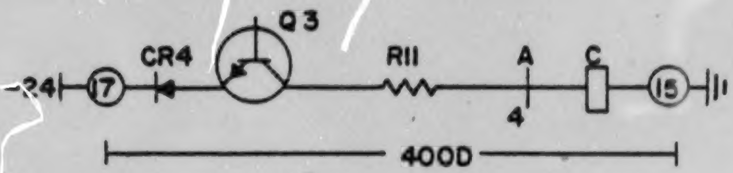


Figure 22. Hold path for C relay.

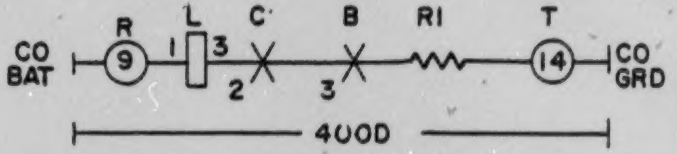


Figure 23. Holding (loop) circuit.

5-15. **Answering.** An incoming call is answered by operating the PICKUP key with the flashing light and picking up the handset. The station is then connected across the line through the hookswitch and key contacts and ringing is tripped at the central office. Ground is connected to the A lead through the hookswitch and key contacts causing the operation of the A relay.

(1) Relay A, operated, makes the following circuit changes:

- Contact 3 makes, shunting the 1-3 winding of the L relay to prevent it from operating on line current.
- Connects - 24 volts to the winding of the C relay causing its operation (contact 4).

(2) Relay C operated:

- Disconnects the - end of CT from the base circuit of Q1 and connects resistor R6 across CT causing it to discharge (contact 5). Transistor Q1 turns on immediately causing Q2 and Q3 to turn off and release relay B.
- Removes the center tap of the ringup bridge from the rest of the circuit, thereby preventing the introduction of noise into the talking circuit (contact 4).
- Disconnects the secondary of the L relay (contact 6).
- Opens the RC lead to discontinue ringing (contact 3).

(3) Relay A and C together:

- Establish the talking path from the telephone to the central office through the KTU circuit, and connect the 10-volt ac to the light in the telephone for a steady busy light. Review the sequence in figure 19.

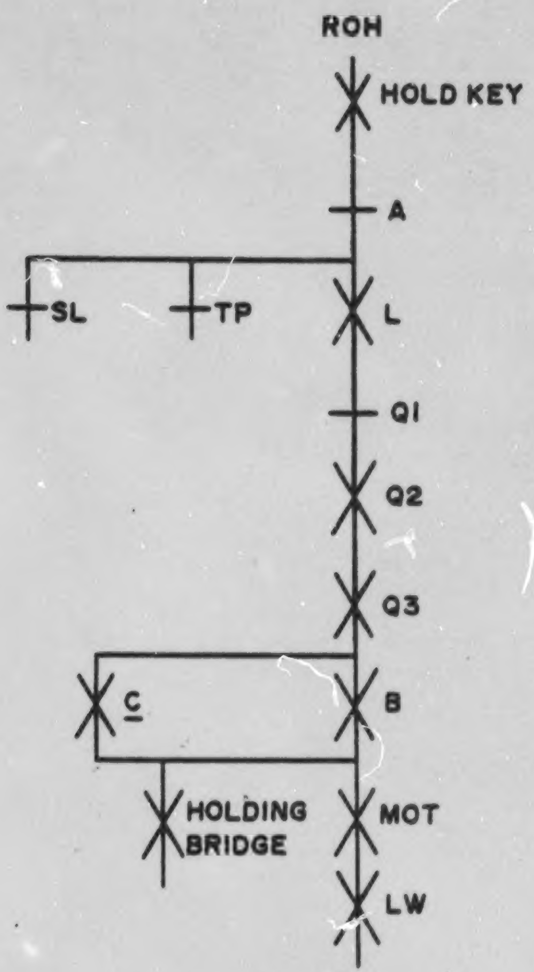


Figure 24. Holding sequence.

NOTE: The procedure for making an outgoing call is the same as that for answering a call except that transistors Q2 and Q3 are normally off and relay B is released.

5-16. **Holding.** A busy line is held by operating the HOLD key on the telephone. When the HOLD key is depressed, ground is disconnected from the A relay causing the A relay to release. The A relay contact, which is shunting the L relay primary, opens; and since the station has not yet disconnected from the line, the L relay operates on line current. Figure 20 shows a sketch of the L relay operate circuit.

5-17. Operation of the L relay causes the base circuit of Q1 to be connected through resistor R3, diode CR6, and the operated C relay contact to -24 volts. The voltage at terminal 2 of the L relay contact drops to nearly -24 volts. This will cause Q1 to turn off, and Q2 and Q3 to turn on. Figure 21 shows the circuit for the negative bias to turn Q1 off.

5-18. Q3 will have turned on about 3 milliseconds after relay A releases, and a hold path is thereby provided for relay C through R11, Q3, and CR4 to -24 volts. See figure 22 for a sketch of this circuit. Q3 operating also provides an operate path for the relay B.

5-19. Relays B and C operated connect the hold resistor R1 in series with the primary of the L relay across the line. This provides the loop to hold the central office equipment. See figure 23 for a sketch of this circuit in the KTU, then analyze the sequence chart in figure 24. In addition, the B and C relays connect the LG lead to the ST lead, and connect the L lead to the LW lead (Y option) or to 10VAC (X option). When the HOLD key is released, the station is disconnected from the line. Line current through the L relay and R1 maintains the circuit in the hold state.

5-20. **Release of the Holding Bridge.** Any station of the key system that seizes the line by operating the associated PICKUP key and going off-hook will cause the A relay to operate and shunt the primary of the L relay, which releases. Transistor Q1 then turns on and Q2 and Q3 turn off, releasing the B relay. Relay C is held operated by the A relay. The circuit is thus restored to the busy state.

5-21. When all stations hang up, the A1 lead is disconnected from the A lead allowing the A relay to release. Release of the A relay opens the holding path for the C relay which in turn releases. Q1 turns on and Q2 and Q3 turn off. The circuit is again in the idle condition, ready to accept another call.

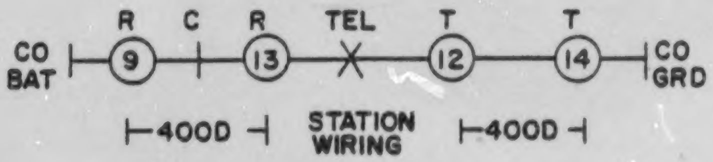


Figure 25. Power failure talk path.

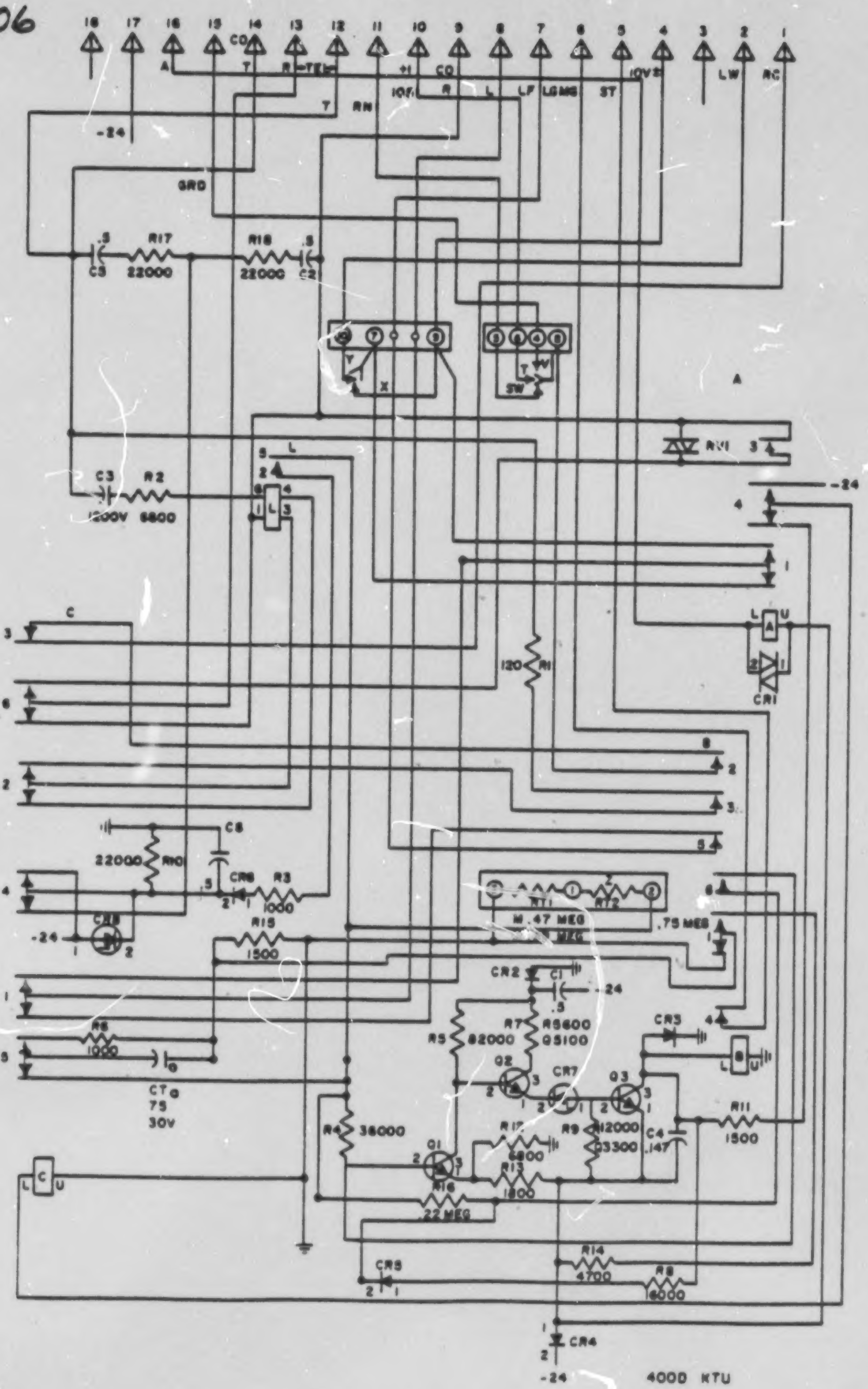

18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
-24
A
T
R
TE
CO
T
RN
+I
CO
10R
R
L
LF
LGMG
ST
10V
LW
RC
GRD
C5
R17
22000
R18
22000
C2
X
SW
A
RV1
C3
R2
1200V
6800
L
-24
C
R1
120
CR1
R10
22000
C8
CR6
R3
1000
CR8
R15
1500
R6
1000
CT
75
30V
RT1
RT2
.75 MEG
CR2
C1
R5
82000
R7
R5600
95100
Q2
CR7
Q3
CR3
R4
36000
Q1
R12
6800
R9
12000
33300
C4
.147
R11
1500
R13
1800
R16
.22 MEG
CR5
R14
4700
R8
16000
CR4
-24
4000 KTU

Figure 26. 400D KTU.

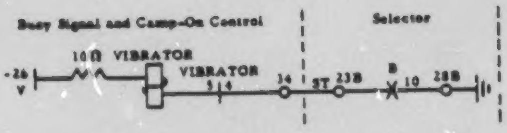

Busy Signal and Camp-On Control
Selector
10Ω VIBRATOR
VIBRATOR
-24 V
34
ST
23B
B
10
28B

Figure 27. Operational sketch of vibrator circuit.

5-22. During periods when the local power supply is inoperative because of power failure, it is still possible to make an outgoing call. When the hookswitch is closed and the PICKUP button is operated, the connection to the line is metallic, as shown in figure 25. Both windings of L relay are connected in series with R2 and C3 across the line but this has a negligible effect on the conversation. No incoming calls will be signaled unless ringers are bridged across the line. Lights and common audible signals will be inoperative. This is the same condition as would exist in any other key system during power failures. At this time, retrace in figure 26 the circuit connections described in this section.

6. 6A Key Telephone System Operation

6-1. We learned that more than one unit has been developed to provide the incoming signal identification function. It is conceivable, then, that more than one device will provide the key system intercommunications. The 6A permits functions that the 207 KTU did not provide. For example, two private talking channels are available, a camp-on feature is provided, and you can make conference calls. Additional services will be noted when we describe the circuits. NOTE: The 6A does not provide any of the incoming line services furnished by the 1A1 or 1A2 key systems; it is combined with either to provide the intercommunications.

6-2. The 6A key system does compare with the 1A1 key system, however. The similarity is that individual units are assembled and wired at the factory and are combined, as required, to provide the desired features. Yet, units manufactured by one company may not be compatible with units furnished by a second company. Consequently, the normal practice is to order all units for your system from one manufacturer. If you must order a replacement KTU from a second company, make sure that it is identical in size, operation, and connections with the one to be replaced.

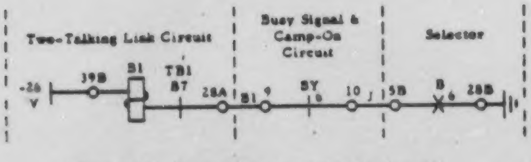

Two-Talking Link Circuit
Busy Signal & Camp-On Circuit
Selector
-24 V
39B
B1
TB1
B7
28A
B1
BY
10
5B
B
28B

Figure 28. Operating circuit of relay B1.

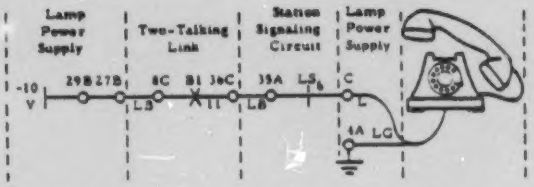

Lamp Power Supply
Two-Talking Link
Station Signaling Circuit
Lamp Power Supply
-10 V
29B
27B
8C
B1
36C
35A
LS
C
LB
LB
LB
L
4A
LG

Figure 29. Telephone station lamp circuit.

6-3. 6A Equipment Seizure. We saw that the intercommunications system enables you to dial a selected station using either one digit or two digits. The same dial selective intercom KTU that we studied earlier is included as a unit of the 6A system. Therefore, we will review its actions while showing additional wiring and its effects on equipment that operates in association with it. To illustrate, by pressing the INTERCOM key and lifting the handset you operate the A relay in the dial selective intercom KTU. Trace foldout 3 to learn the additional devices that make up the operating circuit for the A relay. Although the L relay of the station signaling circuit also operates at this time, it performs only a preparatory function for a future operation. As we noted in Section 4, of this volume, the operated relay A completed the operating circuit of relay B. Now, tracing each

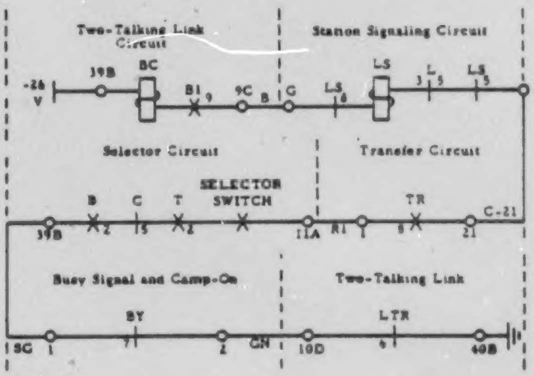

Two-Talking Link Circuit
Station Signaling Circuit
-24 V
39B
BC
B1
9C
B
G
LS
LS
L
LS
F
Selector Circuit
Transfer Circuit
SELECTOR SWITCH
B
C
T
TR
C-21
39B
11A
R1
21
Busy Signal and Camp-On
Two-Talking Link
BY
LTR
SG
CN
10D
40B

Figure 30. Line drawing of operating circuit for relay BC.

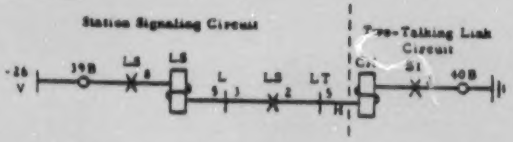

Station Signaling Circuit
Two-Talking Link Circuit
-26 V
39B
LS
8
LS
L
5
3
LS
2
LT
5
H
C
B1
40B

Figure 31. Locking circuit for relay LS of 6A key system.

pair [illegible] contacts on the operated B relay discloses additional circuits. Contact M10 completes the circuit for the vibrator, which provides busy/dial tone. Figure 27 shows the vibrator circuit. Operated contact M1 of the lamp circuit, which we viewed earlier, and contacts EM12 could provide lamp features; however, they are not functional when using the dial selective intercom unit with a 6A key system. Operated contact EMB6 connects ground to the operating circuit of relay B1 in the two-talking link circuit. Figure 28 traces this relay circuit, which is shown in foldout 3. This effort insures that you understand the operating principles of a 6A key system.

6-4. The operated B1 relay in the link circuit completes a telephone set lamp circuit, connects ground to the operating circuit of the ST relay in the 232B KTU (providing this unit is furnished), and connects ground to the time-out (TO) relay circuit. Figure 29 illustrates a busy lamp circuit. Remember: The operated ST relay starts an interrupter or motor which will interrupt the lamp circuit regularly when you desire a flashing lamp. Also, we have traced the ST and TO relay circuits on foldout 3 because they were available; however, the 10B and 18A punchings (terminals) of the link circuit could be connected to any other unit containing a TO or an ST relay.

6-5. The operated vibrator provides dial tone to the telephone set user if this optional feature is desired. Of course, you press the INTERCOM key and lift the telephone handset to get dial tone. Dial tone requires another KTU (227B), which we will not cover.

6-6. **Dialing.** While you are dialing, the release and reoperation of the A relay occurs as described previously. Thus, the selector switch steps and relays C and T operate as a result. Additional relays must operate when double digits are dialed. Digit 2 is used for transfer purposes.

6-7. Having finished your dialing, you await the indication that the called party has lifted the telephone handset. Yet we know that circuit actions are responsible for this signal. Included in these actions are:

a. In the selector circuit,

(1) The A relay operates again, thus reoperating relay B.

(2) Relay C restores after a delay.

(3) Relay T remains operated temporarily following the release of relay C.

b. In the two-talking link circuit,

(1) Relay BC operates. Its operating circuit is the result of the C relay being released and the T relay remaining operated. Figure 30 illustrates the complete circuit. It is evident during your tracing of this circuit on foldout 3 that several optional methods are possible for completing this circuit. For example, ground potential can be connected directly to terminal 39B of the selector circuit, or the potential can be provided under the control of relay LTR in the link circuit and BY in the busy signal and control circuit. We are showing the latter procedure. Regardless of the connecting method, during the slow-to-release period of relay T, you must see relay BC operate. Although relay LS of the station signaling circuit is connected in series with relay BC, it has too great a load to operate with the current of this circuit.

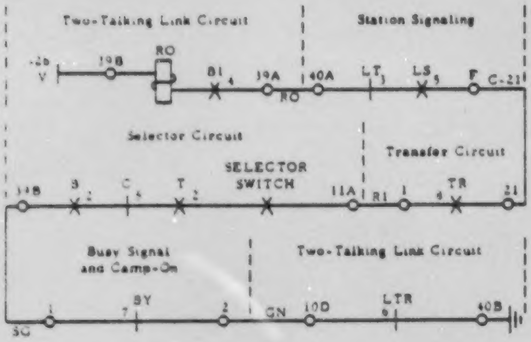

Two-Talking Link Circuit
Station Signaling
-26 V
19B
RO
B1
4
19A
RO
40A
LT
3
LS
5
F
C-21
Selector Circuit
Transfer Circuit
SELECTOR SWITCH
14B
B
2
C
6
T
2
11A
R1
1
4
TR
21
Busy Signal and Camp-On
Two-Talking Link Circuit
SG
1
7
BY
2
GN
10D
LTR
6
40B

Figure 32. Line drawing showing operating circuit for relay RO.

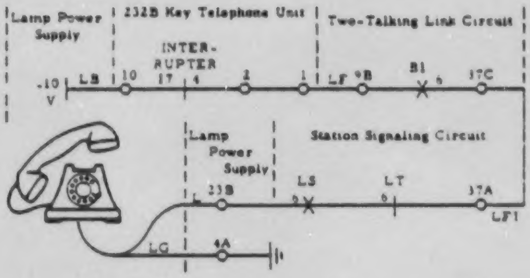

Lamp Power Supply
232B Key Telephone Unit
Two-Talking Link Circuit
INTER-RUPTER
-10 V
LB
10
17
4
2
1
LF
9B
B1
6
37C
Lamp Power Supply
Station Signaling Circuit
L
23B
LS
9
LT
6
37A
LF1
LG
4A

Figure 33. Lamp circuit for indicating an unanswered call.

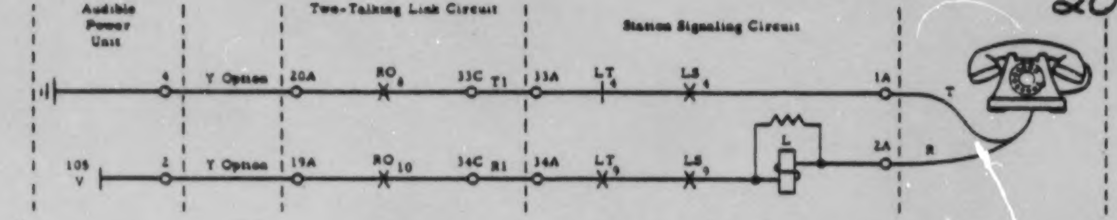


Figure 34. Simplified drawing of 6A key system ringing circuit.

(2) Relay BC1 operates. Operated contact M6 of relay BC completes the operating circuit for relay BC1. Operated contacts EMB6 and B7 open a circuit for relay TB1. Operated contact M2 of relay BC1 shunts the 9100-ohm resistance of relay BC, thus increasing the current for relay LS. Consequently, the contacts of relay LS for the called station move to the operated position. The released BC relay, in turn, restores relay BC1. Relay LS does not restore, however, because its operated contact EMB8 has completed a locking circuit. Figure 31 shows this locking circuit.

(3) Relay RO operates. Operated contact BM5 of relay LS completes the operating circuit for relay RO. Figure 32 illustrates the RO relay circuit. This circuit is made possible because of a wiring option referred to as the AL option where terminal 39A of the two-talking link circuit is connected with terminal 40A of the station signaling circuit.

c. In the station signaling circuit,

(1) Relay LS operates. The operating and locking circuits for relay LS have already been described. The CH relay in the LS relay locking circuit has too little current to operate at this time. Operated contact EBM6 of relay LS completes the flashing lamp circuit for the called telephone set. Figure 33 illustrates this flashing lamp circuit.. We have used terminal 23B rather than terminal C, as shown in foldout 3, because C is a reference designation for the third terminals. Look at the punching chart between figures 2 and 19 on foldout 3, and you will see where this 23B determination was obtained. Parallel to the C reference are 3A, 13A, 23A, etc. For circuit 7 (station 7), 23B is shown as the proper punching to use. Remember: Contact 4 of the interrupter unit is operated at regular intervals when the interrupter is operating. Operated relay ST started it to operating. Operated contacts PMEB4 and PMEB9 of relay LS complete a ringing circuit for the called telephone. Tracing figure 34 and foldout 3 discloses that this circuit is made possible by connecting terminal 20A of the two-talking link circuit with terminal 4 (ring ground) at the audible power unit and terminal 19A with the 105V ringing terminal (2) at the audible power unit. Of course, other connecting options are possible, but most of them include operated contacts of relays RO and LS.

d. In the optional wiring,

(1) AK option. We may choose the AK option to place the RO relay operating circuit under control of the interrupter. Thus, the released RO relay breaks the ringer circuit at intervals. This interruption results in a 1-second operate and 3-second release timing cycle. An interrupted signal may be provided to the calling station as a ringback tone. The released T relay in the selector circuit completes the operating circuit for the release magnet. We observed this effect in paragraph 4-23.

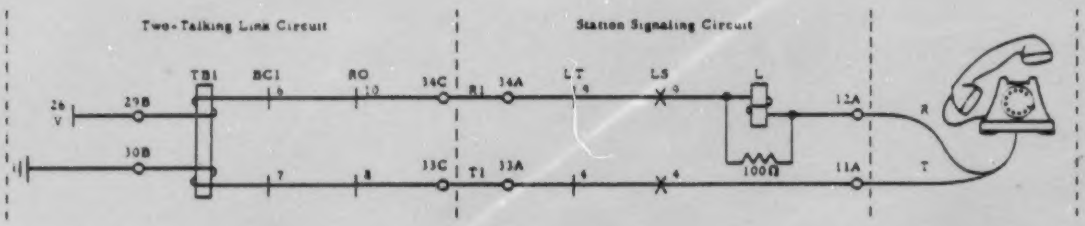


Figure 35. Line drawing of operating circuit for relay TB1.

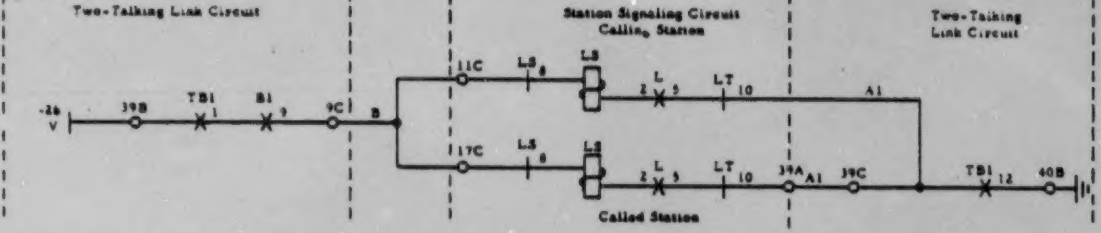

Two-Talking Link Circuit
Station Signaling Circuit
Calling Station
Two-Talking Link Circuit
-26 V
39B
TB1 1
B1 9
9C
B
11C
LS 8
LS
2 L 5
LT 10
A1
17C
LS 8
LS
2 L 5
LT 10
39A A1
39C
TB1 12
40B
Called Station

Figure 36. Operating circuit for relay LS.

(2) AL option. Whereby the restored T relay opens the operating circuit of relay RO in the two-talking link circuit. Hence, the selector switch returns to its original position. Relay LS at the called station will not release, although relay L operates following your lifting of the handset, because of its slow-to-release characteristics.

6-8. If the telephone set is installed with a SIGNAL key in place of one PICKUP key, the operated key operates relay BC of the two-talking link circuit. The operated BC, in turn, completes the BC1 relay's circuit. Your review of the preceding paragraph will disclose again what additional conditions occur after relay BC1 operates. The audible signal at the called station will continue as long as the signal key is pressed.

6-9. Answering Incoming Call. Having lifted the handset at the called station in response to the signals, you operated the TB1 relay in the two-talking link circuit. Figure 35 illustrates this relay operating circuit. The operated L relay in the circuit opens the preliminary holding circuit for relay LS of the station signaling circuit at the called station; however, operated contacts M1 and M12 of relay TB1 renew the circuit again. At the same time, relay LS at the calling station is operated. Figure 36 represents the LS relay circuit. Operated contact B7 or relay TB1 opens the operating circuit of relay B1. Operated contact EBM8 of relay LS again completes the locking circuit for relay LS. This connection is necessary because restored contact M9 of relay B1 removes the preliminary battery connection. Operated contact M4 of relay TB1 provides the power for the lamp circuit of the telephone; thus, it replaces contact M11 of the restored B1 relay. Operated contacts PMEB4 and PMEB9 of relay LS of the calling telephone open the operating circuit of relay A in the selector circuit. Restored relay A opens the operating circuit of relay B. Therefore, the relays that initially processed the call are now released. Figure 37 shows the talking circuit between the two telephone sets. You should also be aware, now, that the power for this conversation passes through relay TB1.

6-10. Operated contact M6 of relay TB1 completes the operating circuit of relay LTR in the two-talking link circuit. Operated contact M2 of relay LTR completes an operating circuit for the LT relays at both stations. Operated contacts PMEB4 and PMEB9 of relay LT transfer the talking circuit of the telephones from the T1 and R1 leads to the T2 and R2 leads. Consequently, relay TB1 is released while relay TB2 becomes operated. Operated contact M12 of relay TB2

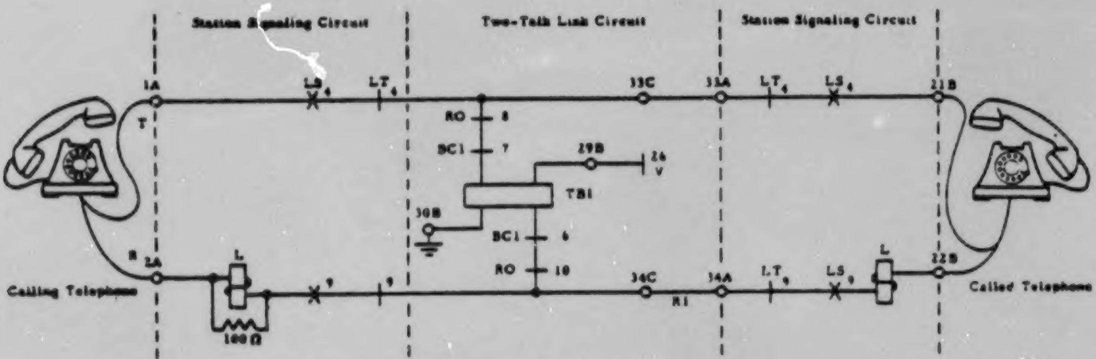

Station Signaling Circuit
Two-Talk Link Circuit
Station Signaling Circuit
1A
T
LS 4
LT 4
33C
33A
LT 4
LS 4
21B
RO 8
BC1 7
29B
26 V
TB1
30B
BC1 6
RO 10
R
2A
L
100 Ω
9
9
34C
R1
34A
LT 9
LS 9
L
22B
Calling Telephone
Called Telephone

Figure 37. Talking circuit in a 6A key system.

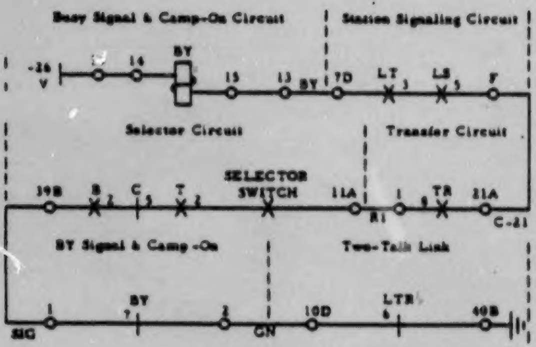

Busy Signal & Camp-On Circuit
Station Signaling Circuit
Selector Circuit
Transfer Circuit
SELECTOR SWITCH
BY Signal & Camp-On
Two-Talk Link
BY
LT
LS
LTR
SIG
GN
C-21

Figure 38. Circuit for operating the BY relay.

completes the operating circuit of relay H and provides ground which holds relay LS operated. Operated contact M2 of relay H provides the holding ground for relay LT. Contact EBM8 on relay H opens the operating circuit of relay LTR. This switching operation is referred to as "transferring from the primary to the secondary talking link." NOTE: You may hear a click during the circuit transfer caused by the battery supply change from relay TB1 to TB2. The result, then, is that two telephone users can have a private conversation while another intercom user can originate and complete a call to a fourth party in the system. The second call would be completed through the operations of relays A, B, C, T, ROT A, RLS A, R1, TR, B1, CH, BC, BC1, RO, and TB1 which are shown on foldout 3.

6-11. Only those people at the stations which are connected to the primary link at time of transfer to the secondary are able to converse. No other person can enter the connection. This limiting provision is referred to as "automatic cutoff." Again, a wiring option determines whether you provide this isolation or not. We noted that relay B1 was restored. Its release opens the operating circuits for LS relays at the stations which are to be cut off. We also saw that operated contact M1 of relay TB1 provides the battery for the LS relays which are to remain operated at the two stations that will be connected for conversation.

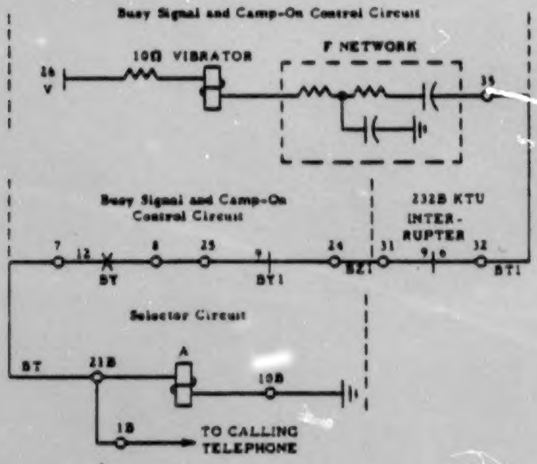

Busy Signal and Camp-On Control Circuit
10Ω VIBRATOR
F NETWORK
Busy Signal and Camp-On Control Circuit
232B KTU INTERRUPTER
Selector Circuit
TO CALLING TELEPHONE

Figure 39. 6A key system busy tone circuit.

6-12. Called Station Busy. You realize, however, that the desired station could be unavailable because of a conversation already in progress. When this condition exists, the originated call operates the BY relay of the busy signal and camp-on control circuit. Figure 38 illustrates an operating circuit for relay BY. Likewise, if you have provided the dial tone option to the system, the attempted call must operate the relay in the ringing and tone control circuit which opens the dial tone circuit. The operated BY relay completes circuits for holding itself operated, flashing the station lamp, and returning busy tone to the calling station. Operated contact M2 of relay BY connects ground to terminal 22 of the busy signal control circuit, and, in turn, this terminal is connected to the circuit having the relay which flashes the lamp. Operated contact M4 of relay BY connects ground to the operating circuit of the vibrator, which provides the busy tone to the calling station. Figure 39 depicts the busy tone circuit. Operated contact M1 of relay BY completes a locking circuit for relay T in the selector equipment.

6-13. When both talking links are busy, camp-on is provided for some systems. If this feature is available, the calling party dials the code number to select the station. This action reserves the system for his call when the station becomes idle again. The selected station is automatically signaled by the system equipment. NOTE: This camp-on

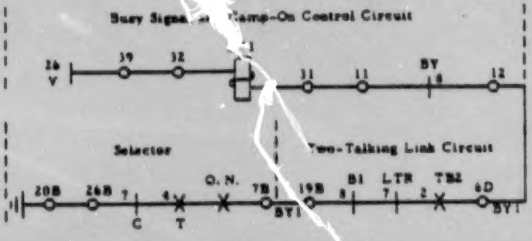

Busy Signal and Camp-On Control Circuit
Selector
Two-Talking Link Circuit
BY
O.N.
TB
B1
LTR
TB2
C
T
BY1

Figure 40. Simplified drawing of operating circuit for relay BY1.

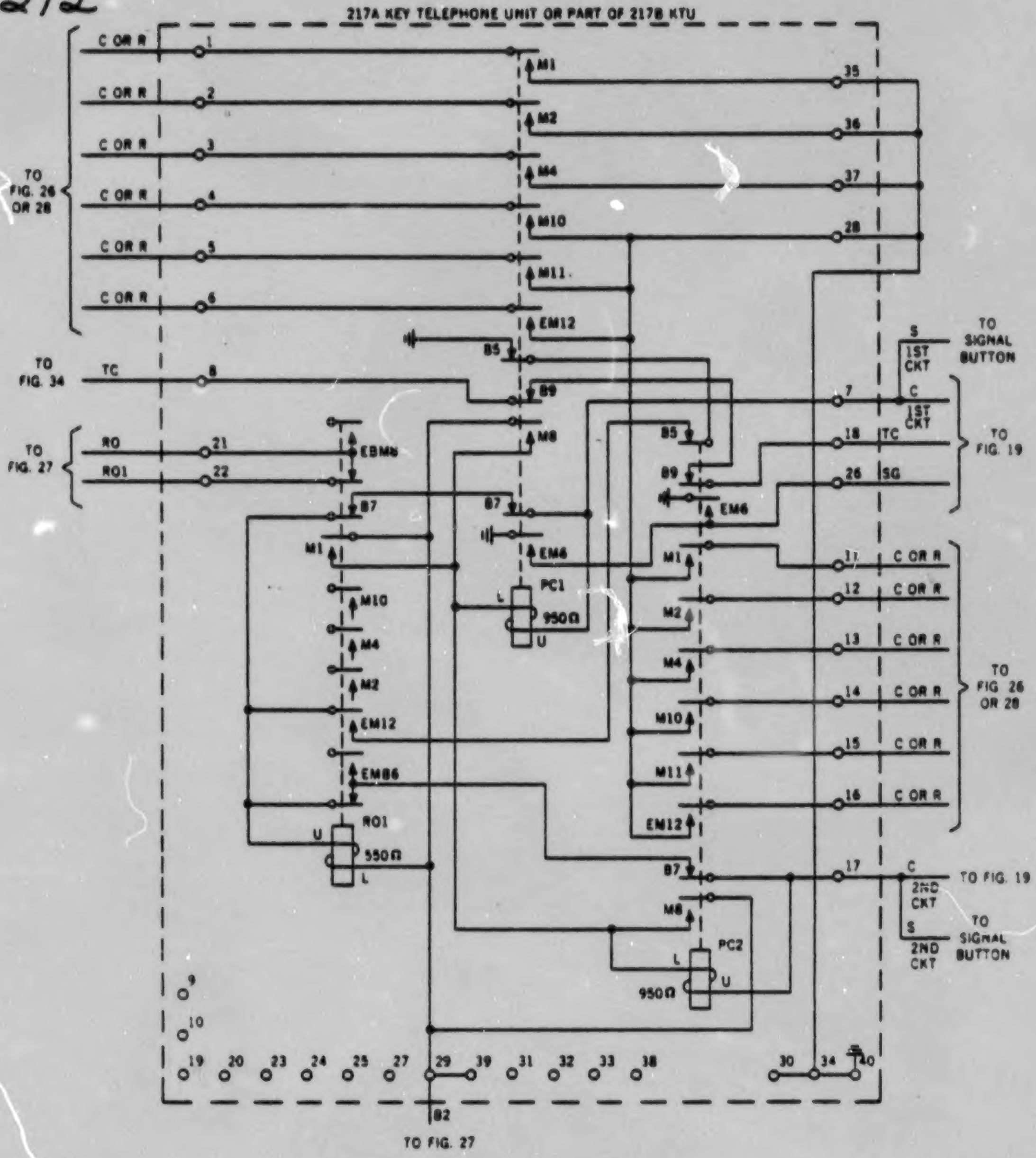

217A KEY TELEPHONE UNIT OR PART OF 217B KTU
TO FIG. 26 OR 28
C OR R
TO FIG. 34
TC
TO FIG. 27
RO
RO1
M1
M2
M4
M10
M11
EM12
B5
B9
M8
EBM8
B7
EM6
PC1
950Ω
RO1
550Ω
PC2
950Ω
S
1ST CKT
C
TO SIGNAL BUTTON
TO FIG. 19
TC
SG
2ND CKT
TO FIG. 19
B2
TO FIG. 27

Figure 41. Schematic diagram of preset conference circuit.

feature is not possible without using a selector circuit, hence cannot be used with the station using a signal key only. You make your selection although the lamps reflect a busy condition. The selector relay A functions as stated in the preceding description. Also, the dialed code digit activates the selector circuit as formerly shown. The operated OFF-NORMAL switch on the selector provides the connection that operates relay BY1 in the busy signal and camp-on control circuit. Figure 40 illustrates the operating circuit for relay BY1. Remember: In this circumstance where both links are busy, relay BY1 operates before relay BY. Contact BM5 of operated BY1 opens the locking circuit of relay BY, while contacts EBM6, BM7, and PMEB4 open the ground connection of the flashing lamp, vibrator, and relay T circuits. Operated contact BM3 of relay BY1, however, completes the operating circuit of relay BY. Operated contact EBM8 of relay BY opens the operating circuit of relay BY1. Since relay BY1 is slow to release, a period of time will pass before any other actions occur. After the BY1 relay has released, the connections are made which we described in paragraph 6-12. For example, relays T and BY are locked operated and busy tone is connected to the incoming relay circuit. Following the completion of the calls on both links, the BY relay restores because of the open contact M2 at relay TB2 and contact M8 of relay TB1. Contact B7 of released relay TB1 completes the operating circuit of relay B1 in the two-talking link circuit, whereas open contact M1 of relay BY permits relay T of the selector to start its timing cycle toward release. Accordingly, relay BC in the two-talking link circuit operates in series with relay LS. Then, relay BC1 operates and shunts relay BC. The activities that follow this BC relay restoration were described in paragraph 6-7.

6-14. Remember: if the desired station is busy on the secondary link, yet the primary link is free, the same response occurs except BY1 does not operate. Relay B1 controls the circuit that operates relay BY1.

6-15. Another 6A system may contain the 224B KTU, which allows the idle station to be signaled when the primary link is released although the secondary link is still busy. The equipment that we have described does not have this provision: Both links must become idle before the desired station can be signaled.

6-16. **Preset Conference Circuit.** A conversation that includes more than two stations is referred to as a "conference call." When the control equipment and method for providing this type of call are established before the call is originated, the connection is referred to as a "preset conference." Yet, we have learned that it is not normally possible to dial more than one station because the two-talking link circuit isolates the call to two stations on each of the two links. Thus, a method had to be provided where the transfer to the secondary link is delayed until all stations for the conference have answered. This delay is provided by using another 6A system equipment unit. Figure 41 is a schematic of a preset conference unit.

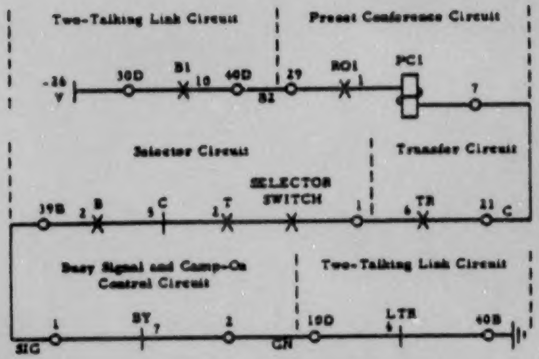

Two-Talking Link Circuit
Preset Conference Circuit
-24 V
30D
B1
10
40D
B1
29
RO1
1
PC1
7
Selector Circuit
Transfer Circuit
SELECTOR SWITCH
19B
2 B
3 C
2 T
1
6 TR
11 C
Busy Signal and Camp-On Control Circuit
Two-Talking Link Circuit
1
BY 7
2
19D
LTR 6
40B
SIG
GN

Figure 42. Line drawing of circuit that operates PC1.

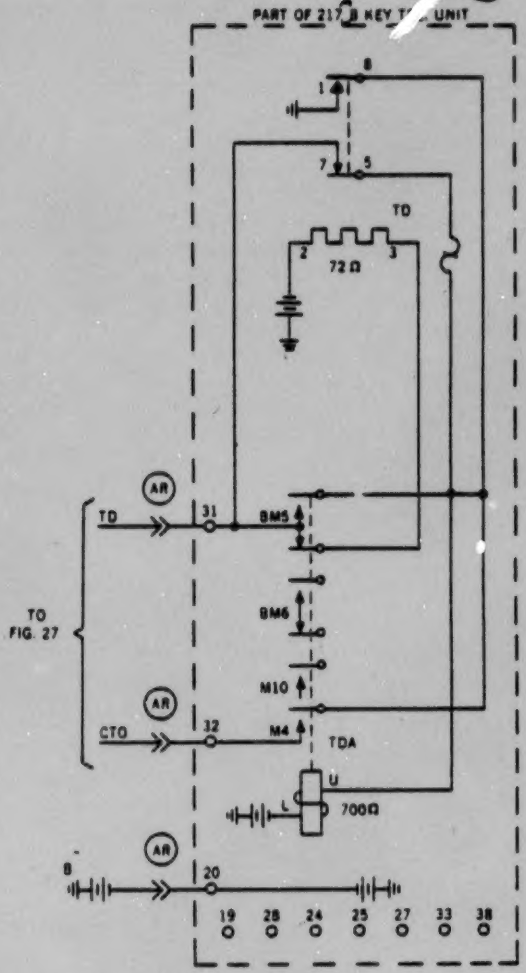

PART OF 217 B KEY T UNIT
8
1
7
5
TD
2
72 Ω
3
AR
TD
31
BM5
BM6
TO FIG. 27
M10
AR
CTO
32
M4
TDA
U
L
700Ω
AR
B
20
19
28
24
25
27
33
38

Figure 43. Schematic diagram of conference time-out circuit.

6-17. You should be aware that pushbutton signaling is possible; however, this provision is not the most desirable because the dial arrangement provides better utilization. We will show that the preset conference unit permits signaling of all conference stations of the system at the same time by dialing a special code digit or by pressing one pushbutton. You know that the operated dial or pushbutton activates relays. Reviewing the selector circuit, we recall that relay C releases before relay T, and that during the time that this condition exists, a ground potential is connected to a C lead of the selector. This grounded circuit includes EMB6 of relay LTR, contact B7 of relay BY, terminal 39B, contact B5 of relay C, and contact M2 of relay T in the selector. The grounded C lead is now connected to terminal 17 of the preset conference circuit. As a result, relay RO1 will operate. Operated contact M1 of relay RO1 completes the operating circuit of relay PC1 or PC2. Figure 42 illustrates the operating circuit for relay PC1. NOTE: If several stations are organized into group 1, they will be connected in a manner that enables relay PC1 to signal them. Using the same method, PC2 operates when the several stations forming group 2 are selected by ground on the C lead connected to the preset conference circuit. Operated contact EMB8 of relay RO1 opens the operating circuit of relay RO in the two-talking link circuit, thereby preventing signaling of any station until all the LS relays for this group of stations have operated. Operated contact EM12 of relay RO1 provides a second operating circuit for relay RO1. It is evident that the ground potential for this additional circuit is connected to contact B5 of relay PC1.

6-18. Your analysis of the results from having operated relay PC1 should disclose that 8 of the 11 contacts have *made* connections. Six contacts complete a connection between ground and the C leads that extend to the LS relays for the six desired stations of thyconference. Remember: Relay LS is installed in series with relay BC of the two-talking link circuit and operates only when relay BC1 shunts the winding of relay BC. Operated contact M8 of relay PC1 completes a locking circuit for relay PC1. Operated contact EMB6 connects ground to the SG lead of the unit, which also connects to the selector circuit. This ground will be extended by the contacts of the selector relays to the C lead. Operated contact B5 of relay PC1 opens the locking circuit of relay RO1, whereas operated contact B7 of relay PC1 also removes ground from relay RO1.

6-19. The six operated LS relays in the station signaling circuits complete a locking circuit that includes relay CH of the two-talking link circuits. This circuit was shown previously. Also, you learned that operated contact EBM6 of each LS relay completes the lamp circuit for the station. Of course, all lamps are flashing now because the circuit is being interrupted. The released RO1 relay in the preset conference unit closed contact EBM8 and the operated LS relay closed contact BM5; thus relay RO of the two-talking link circuit operates. Consequently, it provides ringing current to the six stations. The ringing provision was described in a previous paragraph.

6-20. The released T relay in the selector permits the release magnet to restore the selector switch. As a result, relay PC1 of the preset conference circuit is released. The restored contacts of relay PC1 open the circuits to relays LS and RO. Since the LS relays are locked operated, they are not affected, but relay RO is released. Consequently, the audible signal is silenced.

6-21. The first called station to answer operates the TB1 relay. This relay operating procedure follows the same plan already described, except that relay B1 remains operated until all stations have answered the signal. To illustrate, the hookswitch, depressed pushbutton, and telephone network complete a circuit consisting of contacts on relays LS, LT, RO, BC1, and the winding of relay TB1. In addition, operated contact M4 of relay TB1 completes a lamp circuit to the calling station; however, the lamp will flash until all stations have answered because contact EBM6 of relay B1 continues to provide interrupted power. Operated contact M10 of relay TB1 provides the ground that holds relay B1 operated. Each answered station is connected in parallel for the conference; thus relay TB1 provides the required talking battery. Contact M12 of this latter relay provides the ground that holds the answered stations' LS relays operated.

6-22. When the last station for the conference has answered, the L relay in his signaling circuit operates and removes the final connection for holding the CH relay operated. Consequently, restored contact M6 of relay CH opens the holding circuit of relay B1 and contact B5 of relay CH completes the operating circuit for relay LTR. Now the lamp will burn steadily and the call can be transferred to relay TB2, provided the second link is not busy. We learned that operated relay LTR operates relay LT in the station signaling circuit and relay H. Relays LS and LT, in turn, complete the operating circuit for relay BY when the signaling circuit for the busy station is being held operated. The operated BY relay, then, locks operated, operates the T relay, and causes busy tone to be returned to the station that originated the conference.

6-23. An optional feature that is provided by a 217B KTU is conference time-out. Its function is to stop signaling any unanswered station and allow transfer to occur 30 seconds after the calling station originates the call.

With this option provided, the subscriber originating the conference operates relay B1, thus closing its contact M3. This action connects ground to lead TD which results in heating the bimetallic contacts of a thermal relay. Figure 43 is a portion of a schematic of a 217B showing the time-out circuit using a thermal (TD) relay. Two sets of contacts for this relay operate; however, contacts 1 and 8 operate before 5 and 7. Operated contacts 1 and 8 perform a preparatory action—they connect ground to contacts of relay TDA, thus insuring a rapid response when relay TDA operates. The operated TD relay completes the operating circuit of relay TDA with contacts 5 and 7. Operated contact BM5 of relay TDA opens the operating circuit of relay TD; hence its contacts are permitted to cool. Also, contact BM5 completes the holding circuit for relay TDA. Operated contact M4 of relay TDA connects ground to the CTO lead. It is evident on foldout 3 that the CTO lead is attached to the H lead and the CH relay winding. Grounding this winding results in release of the relay. If you recall the information in the last paragraph, the release of relay CH initiated the transfer from the primary link to the secondary link. Regular calls are not affected by the operation of this time-out circuit, because relay CH is functional only during a conference call.

6-24. We have learned that a key system is flexible because of the optional wiring methods and the operational KTUs for the installation. As a result, you may use different operational procedures for the system. To illustrate, the preset conference installation that we described required that you dial a number to originate the call. Also, we revealed that it was possible to have two groups of six telephones connected for conference. If the organization desires that 12 stations be connected for one conference, you could also provide that. In this latter installation, the dialed conference number would operate relays PC1 and PC2 (strapped) simultaneously. We know, too, that a signal button could be used to originate a conference call. Usually, one party would be authorized to originate the conference call; therefore only his depressed pushbutton permits the equipment actions that result in the conference connection. Of course, the operated signal key would then operate relay RO1 in the preset conference circuit, which, in turn, operates the predetermined PC relay.

6-25. You may have received the impression that 12 stations are the maximum number that can be installed with the 6A key system. However, this is not true. The recommended number of stations is 18. With this number of stations, two-talk link intercommunication is permitted—or in other words, two conversations are possible at one time. Accordingly, the system is developed to keep the 10-percent trunking requirement of a telephone system. A 6A system can be expanded to 36 stations, but this installation reduces the trunkin[illegible]uirement to less than 10 percent, becaus[illegible]ly two conversations are yet permitted.

CHAPTER 3

Installation of Key Telephone Systems

ASSUME THAT you have been asked to put a nut on a bolt. This may appear to be a simple project. However, you must do some planning. For example, you should consider first whether the bolt is to be set within a sink (cavity); if not, it may require a regular washer. Secondly, you probably need to consider if the nut should follow a lockwasher. The project may not be easy, either, because the unit may have to be installed where movement is restricted and where you are unable to see your work. Thus, you may have to use special tools.

2. Similarly, to insure that a key telephone system will give the desired service, you must do some preinstallation planning. As a result, installation time and costs are reduced. Also, a well-planned, orderly installation will require few later changes and little maintenance. Things to consider during planning of the installation include:

a. Operating services and facilities that are to be provided by the system.

b. Specific equipment necessary for providing these services and facilities. Equipment must be sometimes reserved before you order it, to insure its availability when needed.

c. Equipment and cable location at the installation site.

d. Provisions for expansion.

e. Local regulations and conditions.

f. A building for housing the equipment.

3. This chapter contains information about installation planning and cut sheet preparation, placement of the equipment apparatus, and installation of the cables.

7. Key System Installation Planning and Cut Sheet Preparation

7-1. If there is to be a minimum of interruptions during the installation, there must be understanding and agreement between supervisors who have control of the facilities that must be available at specific times. You must, therefore, coordinate with the personnel of other agencies. For example, consultation is necessary with the utilities company, central office personnel, outside plant personnel, the base materiel office, and the Air Force installations office. The latter office must have the building in good condition before you begin installing the equipment because the equipment should not be disturbed after it is in place. Similarly, dust must be held to the minimum when equipment is installed because particles of dust can make devices inoperative. Ventilating, air conditioning, and heating must also be provided before beginning the installation; thus, the utilities firm must have ac power connected into the building. The central office and outside plant personnel should have the required incoming central office lines ready for connection to the KTUs. The materiel section will have to provide tools, filing cabinets, and other necessary building furnishings.

7-2. The preparation of cut sheets (connection sheets) is part of this planning. In a commercial installation, the cut sheet might be made by an engineer in the front office and sent to the installer. In the Air Force, the telephone installer may find himself acting as the engineer.

7-3. You must have the knowledge of how the circuits operate. In addition, you must know the requirements of the requesting agency so that you can select the equipment to be used. This equipment is selected to provide the features that are desired. Then, you can prepare cut sheets.

7-4. A cut sheet is merely a listing of all the connections that must be made to connect and install a key system. This sheet can be made in several different ways. The cut sheet format that we will use is not a standard Air Force form. The installation section at your base may do it differently; however, the method presented here works well.

FEATURE	LEAD DESIGNATION	6481-75 CABLE TERMINAL			TERMINAL ON KTU		TERMINAL ON KTU		TERMINAL ON KTU		TERMINAL ON 207C KTU
		TERMINAL STRIP A	INSIDE WIRING CABLE		232A	232B	230A	230B	202C	202D	
LINE 1	T	1	W	BLUE BINDER			1A-11A	1ST			
	R	2	BL				2A-12A				
	A	3	W				3A-13A				
	A1	4	O				4A-14A				
	LG	5	W				6A-16A				
	L	6	G				5A-15A				
LINE 2	T	7	W				1B-11B				
	R	8	BR				2B-12B				
	A	9	W				3B-13B				
	A1	10	S				4B-14B				
	LG	11	R				6B-16B				
	L	12	BL				5B-15B				
LINE 3	T	13	R				1C-11C				
	R	14	O				2C-12C				
	A	15	R				3C-13C				
	A1	16	G				4C-14C				
	LG	17	R				6C-16C				
	L	18	BR				5C-15C				
LINE 4	T	19	R				1D-11D				
	R	20	S				2D-12D				
	A	21	BK				3D-13D				
	A1	22	BL				4D-14D				
	LG	23	BK				6D-16D				
	L	24	O				5D-15D				

Figure 44. Key system connection sheet.

7-5. The connection sheet shown in figure 44 is a portion of a commonly used one, which shows all connections to be made at the equipment cabinet and run throughout the building for connecting to the individual telephones. Of course, we must connect all CO lines to the appropriate 7 and 8 punchings of the 202Ds or 230Bs. These connections will be shown on the Key System Strapping Sheet, as well as necessary strapping and power connections.

7-6. Systems that are ordered as a package are already mounted and strapped, thus eliminating most strapping and connections. We know, too, that packages are available in a variety of sizes and features so that almost any service can be furnished, prewired. (Refer to Chap. 1.)

8. Placement of Apparatus Cabinets and Equipment

8-1. Our discussion of planning to this point has covered some of the operations in preparation for installing a key system. Before the equipment can actually be installed, we must do some on-site planning, as you will see in the following paragraphs.

8-2. Installation of the apparatus cabinets requires a considerable amount of good judgment on the part of the installer. Several factors should be considered. When selecting a suitable location for the cabinets, you should consider the desires of the attendant. You should also try to visualize the appearance of the installed cabinets. Inconspicuous locations are desirable, but the cabinets must be accessible for maintenance. You must provide adequate support for them; inside plaster block or similar soft materials and temporary office partitions are not suitable. Wall-mounted cabinets should be about eye level to an average man. Additional factors that you should consider are:

a. Building conduit. If a telephone conduit or duct system is provided, locate the cabinets near the outlet.

b. Space. Locate the cabinet so that there is sufficient space for the gate to open. The gate of the cabinet opens from left to right; thus you should provide at least 1 foot of wall

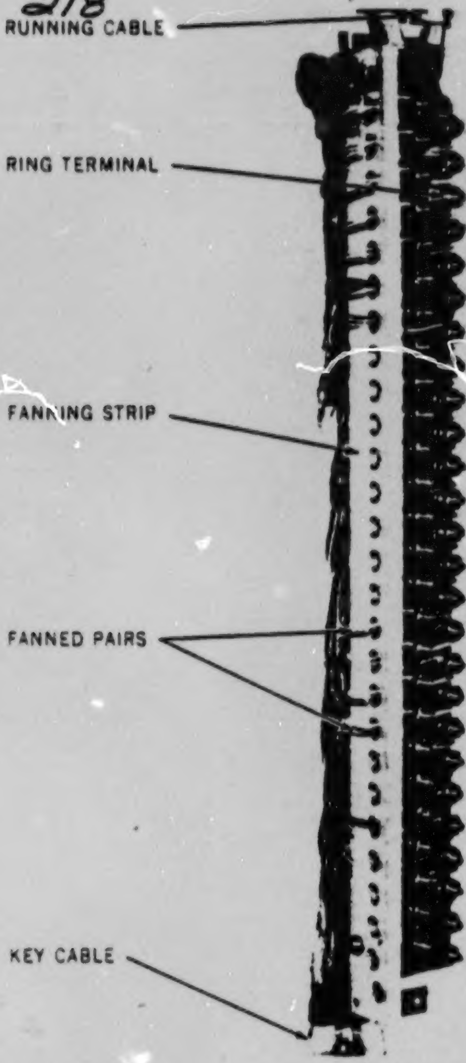

RUNNING CABLE
RING TERMINAL
FANNING STRIP
FANNED PAIRS
KEY CABLE

Figure 45. Fanned cable at type 30 bridging terminal.

space having no obstacles on the right-hand side of the cabinet and about 3 feet clearance to the front.

c. Damage. Where cabinets are to be mounted on the floor, consider the possibility of damage from water or from blows during cleaning. A location close to the wall or partition is usually desirable for cabling purposes.

d. Vibrations. Avoid placing cabinets containing relay equipment in spaces subject to vibration.

e. Heat. Avoid locations near radiators, steam pipes, registers, etc., which would subject the equipment to excessive heat.

f. Light. Good light should be available so that the installer and the repairman can see the operation of the relays.

g. Ventilation. The apparatus cabinet may be placed in a closet or small room if it is opened a few times during the day.

h. Power. There must be provision for power (110 to 120 volts) close to the apparatus cabinet.

9. Termination of Cable

9-1. Since there are many different types of terminating blocks, it is evident that you will use several forming arrangements. At the type 30 terminal unit, you place the running cable on the side where the board fanning

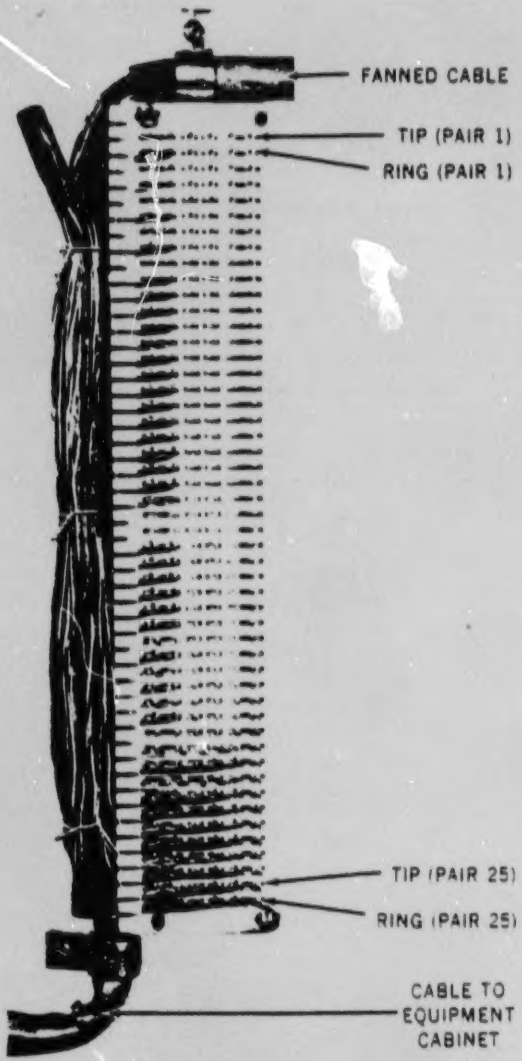

FANNED CABLE
TIP (PAIR 1)
RING (PAIR 1)
TIP (PAIR 25)
RING (PAIR 25)
CABLE TO EQUIPMENT CABINET

Figure 46. Fanned cable at type 66 bridging terminal.

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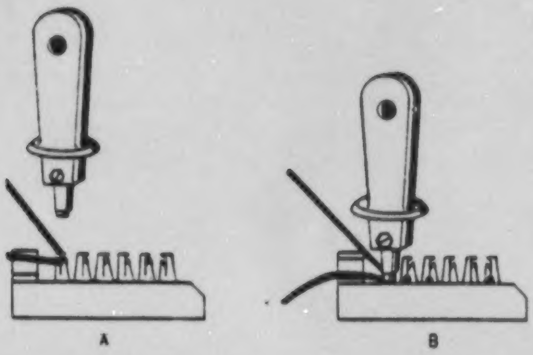

Figure 47. Terminating a wire on a 66A terminal.

strip is installed. The cable should also extend 2 inches below the type 30 terminal before you begin to fan the conductors. The running cable is to be butted in such a manner that the end of the sheath is below the strip and at a distance that permits room for skinning and terminating the first conductors. Figure 45 illustrates a sample fanning arrangement at the type 30 terminal. Accordingly, pair 1 has the shortest conductors and pair 25 has the longest conductors. Since it is more difficult to fan long conductors than short conductors, excess wire should be cut off, leaving only a sufficient length with which to work. Usually, a wire that extends 6 inches beyond the face of the extreme front edge of the fanning strip is sufficient for the skinning and terminating operation. However, wires that are not to be used must not be removed. They are spare wires. Be sure to keep the wires paired while completing the fanning operation, hence arrange them to conform with the D color code. This color code is standard in 25-pair, plastic, 24-AWG cable, which you will use most often. This 25 pair is placed in binders and repeated to make up 50-, 75- or 100-pair cables. Three binders, for example, make a 75-pair cable.

9-2. A much faster, easier method is shown in the terminating pattern used with a type 66 bridging terminal, as illustrated in figure 46. You place the wire in the small opening below the upper finger on one of the projections (clips) for the terminal. Of course, you first insert the wire through the fanning strip before placing the wire in this position. Figure 47,A, shows the wire in position in a terminal clip before it is forced within the lips of the clip. Figure 47,B, shows the 714B tool after it has pressed the wire down, thus completing the termination. It is evident that you do not skin the wire for this type of terminating operation. NOTE: A sharp edge on the blade of the tool cuts off the excess wire. The blade must go onto the clip straight to prevent damage to the tool or to the terminal or both.

9-3. If you want to install a wire that is to continue to another connection, reverse the blade to allow the dull edge of the blade to rest against the wire as it is being pressed down, so as not to cut the wire.

NOTE: The 714B tool (fig. 47) is designed with a reversible blade.

9-4. After having made all connections, including power and incoming CO lines, examine your installation closely to see that all units are wired neatly and correctly. This is often referred to as "preoperational check." It should be thorough to disclose loose or undesirable connections. Also, remember to observe all rules of conduit and wire placement, which you learned in Volume 3. Following this check, you usually perform an operational test, which allows you to test the equipment circuits under simulated working conditions. Circuit descriptions and instructions covering the method of operation for each circuit in the system are furnished with the job drawings and specifications. If you encounter trouble during the operational test, you must determine and correct the fault.

9-5. Remember, the appearance of a telephone installation may cause the user to think your system is defective, although the equipment works. If the connections are made neatly and correctly and the cables are uniformly placed, everybody will be satisfied. There is a statement that fits very well here: "If a job is worth doing, it is worth doing well, and safely!"

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Maintenance and Testing of Key Telephone Systems

THINKING OF, and preparing for, trouble in a communications system is best done before the trouble occurs. One opportunity for thinking about key system troubles is before you in this chapter. Although we cannot describe all the troubles that could occur, we can give common reasons for equipment failures. Of course, you cannot learn to repair the equipment by merely reading words that describe the troubles. Through practice you learn how to clean and adjust relays and make repairs.

1. The methods that we describe may not be identical to the method which you will use, or have used, but it will be similar. All telephone systems have similar electrical circuits; thus comparable methods are used with all systems.

2. From this introduction to key system troubles, you should build toward a thorough understanding of the system. Much of this understanding is gained through your doing the work.

10. Operational Test of Key Telephone Systems

10-1. Some people may regard a key system as just another telephone system with a number of extensions. We, of course, after tracing through the circuits and discussing cabling and interconnections, know that beneath the simple surface appearance lies a rather complex system of relays, contacts, lamps, and wiring. Because of this complexity, our operational checkout should be complete. Every telephone in the key system is an individual unit, independent of the others; therefore, each unit must be carefully checked before we consider the installation completed. It is not enough to pick up only one instrument and test the hold, incoming signal, dial, and intercom features and assume that the system is in order.

10-2. Not only must each phone be checked to see if it will permit talking, receiving, and dialing; but each phone must also be checked to see if it will hold the line; if it will control the line by lighting the busy lamp at all stations; if it will operate through the dial and the intercom; and, most important, if it will do all or any one of these things while other instruments are detached from the line. Each instrument or station must be independently able to pick up all lines, release all lines, pick up the intercom and dial a station, hold each central office line, or perform any other operation that it is supposed to while all other instruments in the system are hung up. Until each complete system is checked out carefully, you cannot be sure that it is properly installed.

10-3. You will realize after having worked with a key telephone system that the results are sometimes unusual because of the common connections.

10-4. The ground connection for the system is very important and should be rechecked as part of the checkout. If the ground is not good, it can cause a great deal of grief. If the ground wire is broken, the trouble indications are unusual. For instance, a broken ground wire in a 1A2 system may result in burned-out transistors of the 400D KTU. From these trouble symptoms you should realize that each system has specific symptoms that occur with an open ground. Other systems may have other symptoms. Be sure that the ground for your system is solid and is protected from damage. If a ground rod is used, make sure that it is driven deeply enough to give a good ground and that it is located in a place where it will not be damaged by grass cutting tools, thus cutting you out of service. Some 1A1 key telephone systems signal just like a selective ringing system—ring to ground (also referred to as "common audible"). All ringing is through ground return to the central office. The system, with the 230B KTU circuit, usually

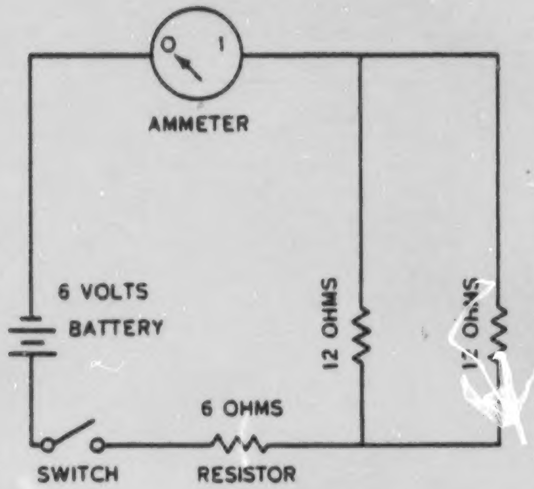

Figure 48. Nonoperating series-parallel electrical circuit.

uses metallic ringing (ring to tip or tip to ring signaling).

10-5. The preceding troubles are just a sample of the trouble that can show up on individual sets or parts of the system. There are many troubles in a 1A1 key system that may affect only one telephone. This is the reason that we say that key system telephones are not extensions but are independent of each other. Before you announce that a system is ready for use, be very sure that you have checked each phone and every feature. These tests are made with no other instrument off the hook.

10-6. **General Procedures.** In the following operational tests you will have a limited need for an assistant. Check the system operation by using the following procedures:

a. Plug in the power unit cord.

NOTE: If at any time you do not get the indication of proper operation, trace your wiring. Troubles in a new installation are most often the result of wire or connection defects, not faulty telephones or equipment.

b. With all other telephones "hung up," lift your telephone handset, press each PICKUP button on the *first* telephone of the system and look for a light under each depressed pushbutton. In addition, dial tone should be heard for each CO line.

c. Determine if the first incoming line can be held by depressing the first PICKUP key and then depressing the HOLD button. The first PICKUP key should be restored by the depressed HOLD pushbutton as the latter button returns to its normal position. Also, the lamp under the first PICKUP key should momentarily go out before lighting again. Its second lighting period is the result of an operated H relay. Of course, if the system includes the winking circuit option, then the lamp will wink while the H relay is operated.

d. Release the H relay by depressing the first PICKUP key. Again the lamp under the pushbutton will go out and then reoperate.

e. Dial the central office number of the second line. Now, you should hear ringing and should see the lamp flash under pushbutton 2. Furthermore, the lamp under pushbutton 1 for your station should also be lighted, but steadily.

f. Answer the ringing signal by depressing the second PICKUP key. The lamp under the pushbutton for the second line at your station should change from flashing to steady. The depressed second key restores PICKUP key 1. Lamp 1 must go out.

g. Return to the first line by depressing PICKUP key 1 again.

h. Dial the central office number for the third incoming line. Again, you should hear ringing and should see the lamp under pushbutton 3 flash. Answer the signal by depressing the third PICKUP button.

i. Follow the same procedure for checking signaling of all additional incoming lines.

j. Advance to PICKUP key 2 and press it. Then dial the central office number of incoming line 1. As a result, the lamp for line 1 should flash.

k. Press the PICKUP key for line 1. Note that lamp 1 should light steadily and lamp 2 will go out following restoration of the second pushbutton.

l. Press PICKUP key 2 and then the HOLD button. Accordingly, lamp 2 will light, go out, and light again, if the H relay for line circuit 2 operates properly. Lamp 1 will go out.

m. Press PICKUP key 2 to release the H relay.

n. Press PICKUP key 3. Look for a lighted lamp and listen for dial tone. Rotate the dial once and note that dial tone ceases.

o. Press the HOLD button and observe the lamp for PICKUP key 3. Again, it should temporarily go out during the transfer to the H relay from relay A.

p. Depress PICKUP key 3 again.

q. Repeat the procedures *n* through *p* while operating the remaining PICKUP keys. (If you are testing a system with more than four PICKUP keys, then use these steps for the additional keys.)

r. Depress the INTERCOM pushbutton and dial "2." As a result, the ringer at the telephone you are using should ring. If you were operating a station other than station 1,

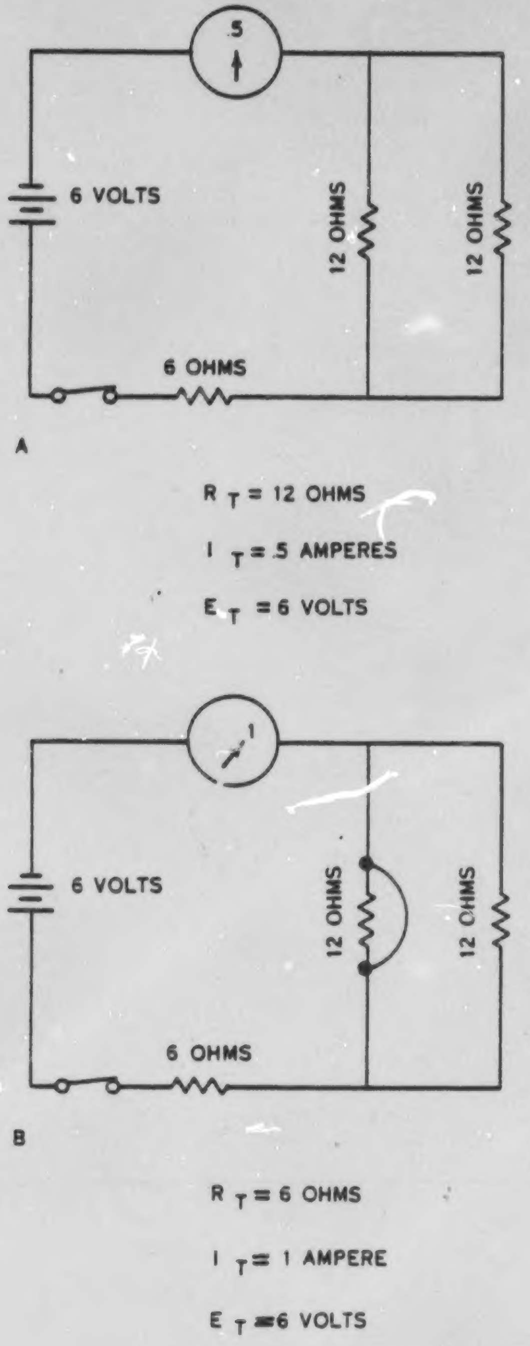

Figure 49. Normal and abnormal responses for a series-parallel circuit.

then you would dial that code to ring the bell. The ringer operates only once. The lamp for the INTERCOM button glows steadily as long as the pushbutton is depressed.

s. To determine the quality of your talking circuit, dial the intercom number for the station where your assistant is located. Following his lifting of the station handset and pressing the INTERCOM button, you should converse. Ask him to listen for the intercom signals for the remaining stations when you dial them. Also, ask him to notify you if anything appears irregular.

t. Dial each of the intercom code assignments and wait approximately 1 minute for a return call, in case of an irregularity.

u. Return your handset to the telephone when you think your operational test of this station is completed.

v. Walk to station 2 and repeat the operational test described in steps *b* through *q*. During the test of the intercom from station 2, you dial the assigned number for that station.

w. Perform this operational test for each of the stations in your key system.

10-7. If exclusion is used, operate the EXCLUSION key after lifting the handset and depressing the first pushbutton at the exclusion station. Then go to a station that is to be excluded and press the first pushbutton and lift the handset. At this excluded station you should have completed silence: no dial tone, no side tone, etc., when the EXCLUSION key is operated.

10-8. We have used one procedure for testing the operation of a newly installed 1A1 key system. You may want to use a procedure that differs from our description. Just remember, use a method that is effective. It must result in checking each circuit and each line at every station. You need not dial the complete assigned number for all called stations of your system when testing an

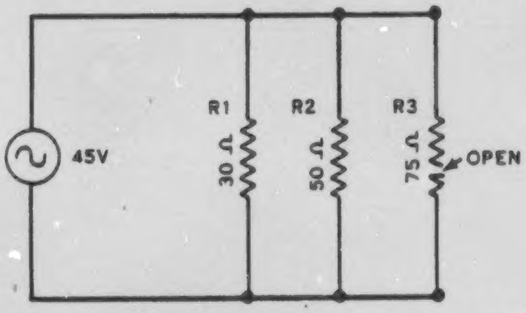

Figure 50. A parallel-connected electrical circuit.

existing system. Dial only one digit and determine if the dial action breaks dial tone. This performance eliminates your signaling an occupied station unnecessarily.

10-9. The operational test will reveal that the features for one are observable on all others. These results are due to the key system telephones being connected in parallel. The operation of the hold circuit relay is checked by pressing first the PICKUP key and then pressing the HOLD pushbutton. In this case the lamp under the PICKUP key should either wink or glow steadily, after momentarily being extinguished. It is evident, however, that you cannot determine the quality of the talking circuit without having an assistant. Remember: All telephone handsets except the one at the station where you are testing must be hung up during an operational test. Use the connection table (cut sheet) to determine the intercom dialing code.

10-10. Your operational check of a 1A2 key system should give the test results and should be done in the same manner as was described in the preceding paragraphs.

10-11. **Checking 6A Key System.** Since the equipment used to provide the 6A intercom includes circuits that are more complex, it is obvious that your operational checks are going to be more difficult than those using only the 207C intercom. You must also check every feature of the system at every station. Each station having a connection to a 6A system has greater independence than it would have if connected only to the 1A1 and 207C. Therefore, a trouble at one station may have no effect on the other stations. An example of this independence is illustrated with the "two-talk link" feature. In this circumstance, when all stations are idle and you depress the PICKUP pushbutton, all lamps operate for that line. This function is the same as that used with the intercom circuit of the 1A1 or 1A2 key system. Now you dial the intercom number of the desired station and, as a result, the line lamp for the selected station flashes and the ringer operates. Yet, the lamps for the intercom circuit at the other stations remain lighted but without the flashing. When the handset is lifted and the PICKUP button pressed at the signaled station, the lamp ceases flashing and the ringer stops. In addition, the lighted lamps at all stations, except the two connected for communicating, go out. You can see, therefore, the reason for saying: "It is most important that every telephone of a 6A system be checked for every feature."

10-12. Let us consider additional operating checks used with the 6A key system, and the indications that denote normal operation. NOTE: To do these tests, you must have assistants at other stations.

a. Paragraph 10-11 described the procedure for connecting to the selected station. You should remember that the first talking circuit connection operated the TB1 relay, which in turn operated TB2 of the secondary link. To advance our operational test a step further, you now talk with the assistant who answers the selected telephone and ask him to stand by while you get another assistant to dial the fourth station. This conversion is possible because of the operated TB2 relay. The third and fourth men follow the prescribed precedure for making the connection. They should then be able to talk without interfering in your conversation with the first assistant, because their talking circuit is completed through the windings of the operated TB1 relay.

b. Since both talking circuits are busy, you should now determine if "camp-on" is possible. You do this by dialing the number of the station occupied by your third assistant. As a result, a busy tone should be returned to your handset receiver. With this response, have your assistants hang up. Immediately, the station ringer for the third assistant should operate and the associated lamp should flash. Hence, the camp-on feature is effective for your station. NOTE: The key system features, for instance camp-on, may be constructed in a number of ways to give slightly different indications. We are not describing each. When you receive your assignment to the Air Force organization, learn what indications to expect with your system and then look for them during future tests.

c. You determine if the preset conference circuit is usable by dialing the assigned number. The called stations and the calling station lamps will flash and the ringer at the called stations operates. Your assistants lift the handsets and depress the buttons showing the flashing lamp at their respective stations. As a result, the ringer stops and the lamp changes to a steady glow. Remember: The lamp at the calling station flashes until the last conference station attendant answers the signal. Now all lamps should light steadily, and conversation should be possible between all conference members. To learn if a busy station causes the system to return a busy signal, request that one assistant hold his handset off the cradle and keep the INTERCOM pushbutton depressed after the others return to the cradle. Then you dial the code number for his station again. Your station will receive a busy signal until the assistant restores the handset to the telephone cradle.

d. Other checks of the 6A key system are comparable to what we have described; therefore we won't emphasize them. For example, you have single-digit and two-digit seizure to test and may have preset conference codes of one and two digits. We repeat: you must test each feature at each station before you consider the installation complete.

e. During your operational testing, observe the responses of the telephone units closely. The dial and the pushbuttons should move freely. Of course, the Call Director has a greater number of buttons to check, but they function the same as the keys on the 560 series telephone. Each telephone, we have learned, must show the proper indications when a call is incoming and must permit good quality transmission when the talking circuits are complete.

11. Isolating Equipment Faults

11-1. Excessive current in an electric circuit is often identified by a blown fuse or an operated circuit breaker. Not all circuit troubles are so readily identified as those in circuits having fuses. Because of the multiplicity of circuit connections, a key system trouble is often difficult to determine. For example: Since it is common practice to leave one pushbutton in the operated position, a lifted handset is the most common reason for that PUSHBUTTON lamp to light. However, any line or equipment short circuit or ground gives the same result as the receiver off the cradle. We realize then that the line, in effect, is made busy by such defects. Some telephone men refer to a line that is continuously busy as having a permanent signal condition because they have worked with equipment which has trouble lamps that remain lighted until the defect is removed. NOTE: Key systems do not have trouble indicator lamps. To identify system circuit troubles, you must know the equipment, know what to look for, and how to use test equipment.

11-2. Permanent troubles are generally found by analysis of circuits and by testing the circuits. The analysis rarely determines a specific component within the unit as being open or short-circuited, but you more often will isolate the fault to a particular unit. Testing with test devices enables you to determine the specific component. You may also see an intermittent (disappearing) open or short. This latter trouble is caused by a loose connection. A visual inspection may be the only method for finding the defect.

11-3. Let us recall basic circuit principles that you know already. These basic principles apply when you analyze any key system circuit.

a. An open circuit has no current because the circuit opposition is infinite. Figure 48 is a simple circuit that has no current because the switch is open.

b. A shorted circuit has less than normal resistance and an increased current. Figure 49 illustrates the effect of a shorted resistor in a series-parallel circuit. Figure 49,A, shows that the normal circuit has .5 ampere, and figure 49,B, reveals that the shorted parallel circuit reduced the circuit resistance to 6 ohms. Consequently, the total current has increased to 1 ampere.

c. Figure 50 shows another circuit effect which you need to consider when recalling circuit principles. The normal total resistance for that circuit is 15 ohms. As a result of the open in the 75-ohm resistor the total resistance becomes 18.75 ohms.

11-4. Although the circuits that we just analyzed are simple, the principles we used are applicable to complex circuits. Most key system defects result in more complex analysis procedures, as the following examples illustrate.

11-5. Assume that you have pressed the PICKUP key and then depressed the HOLD pushbutton but the associated lamp has not lighted. We need to consider whether the trouble is just the lamp, or whether it is relay failure. We know that relay A operates first, followed by relay H. Contacts of both operated relays complete the lamp circuit. You seldom have two relays fail simultaneously; therefore we can assume that the lamp has failed. Replacement of the lamp should correct this trouble.

11-6. Assume that the hold relay was not remaining operated after being energized. Remember: You determine if the relay has operated by observing the lamp under the PICKUP key. What could be the cause for the H relay to restore? The H relay could have neither an open wire nor a short-circuited winding. A defective relay winding, either short-circuited or open, results in failure to operate. We know this to be true because an open winding prevents current, whereas a short circuit bypasses current around the winding. Yet the relay did operate temporarily. Open contacts as the result of a contact spring maladjustment are more likely to be the trouble cause. Open wires are more probable troubles than are shorted wires. However, relay maladjustments are more likely to occur than either of the wire faults.

11-7. Inability to dial could be another trouble symptom. You should understand that many faulty components can result in this symptom. For example, the telephone dial can be defective, the pulsing relay in the selector can be at fault, the companion relays of the pulsing relay can be maladjusted, or the rotary stepping switch in the selector circuit can be erring mechanically. Take a moment to think about this defect. If only one member of the system cannot dial, it is evident that the trouble would not be the selector or its relays and switch. Since there is only one selector KTU (207C) for the system, when its components fail to operate, all telephones in the intercom system are prevented from dialing or they will dial wrong numbers.

11-8. Likewise, if the ringing equipment is faulty, it affects more than one telephone station. Therefore, you may receive more than one trouble report of the same trouble. You may also receive more than one trouble report from the same subscriber. To illustrate, 'bells don't ring," "no audible ringing," "don't answer," and "doesn't get calls" are possible reports that could be received from stations when the ringing equipment is not operating. Systems with lamps and bells for each station will seldom have all these reports returned because the lamps serve as backup signal indicators for the ringer.

11-9. "A conference station for a 6A key system does not answer" could be the trouble report. You learned that this equipment arrangement makes it possible for one originating station to call several other stations simultaneously. If all stations except one have answered, then the ringing equipment cannot be faulty. It is not probable that a soldered strap is going to become open, either. Possible troubles are faulty KTU connections or relay contacts which need burnishing or adjustment.

11-10. There are many trouble symptoms and isolating procedures that we have not discussed. To include all of them would require a chapter of unreasonable length. As you know, the equipment operates because of completed electrical circuits, and basic circuit principles are applicable for all circuits. Perhaps the circuits are used somewhat differently or are constructed in a different manner, but you can easily determine these differences with time and study.

11-11. When you have seen the trouble symptom and have isolated the unit in trouble, is your responsibility ended? No. You must locate the specific trouble within the imperfect unit.

12. Trouble Location in Key Telephone Systems

12-1. Key system troubles are brought to our attention by telephone users or by testmen. As a repairman, you must then determine the specific location of the trouble. Effective troubleshooting results from good procedures, accurate thinking, and practice. Guessing and "inept or foolish fishing for troubles" usually lead to disastrous results. Think logically! If your car fails to stop after you apply pressure on the brake pedal, you would not check the car radio.

12-2. Troubleshooting usually starts with an analysis of the telephone trouble report. Coordinate the trouble report with the schematic diagram for the equipment unit. Quite often you can isolate the fault to a particular component through this coordination. An operational check insures that the report is accurate and it often eliminates possible causes of the trouble, thus revealing the actual cause. Your trouble analysis should begin from the unit in trouble.

12-3. If the preceding actions reveal an open circuit, you can localize the trouble by placing a short circuit near the center of the circuit and by making electrical meter tests from both ends. The circuit end that does not indicate the short must have an open within it. If you determine the circuit has a short, then open the circuit near the center. Test toward the ends of the circuit from that open. The shorted end will be revealed by the test equipment. Remember: This described checking is going to be dependent on the type of circuit with which you are working. You do not short-circuit a live circuit because additional troubles would result. These testing activities are normally made in an isolated (disconnected) defective circuit. Test an idle or dead circuit with the ohmmeter or any other test device that has an internal power source. Some repairman use a buzzer. Using one type of buzzer test set, you operate the buzzer when touching a wire that is good. Conversely, an open wire prevents the buzzer from operating.

12-4. Testing a circuit reveals the condition of its components. Thus, the components are not usually tested

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individually. For instance, we learned that by operating a PICKUP key we operated a lamp. Consequently, you should realize that relay A in the KTU and its associated contacts, which complete the lamp circuit, must be good. Also, the lamp is good and the power circuits for the lamps and relays are functioning. Periodic circuit testing is an effective method of keeping a telephone system in continuous operation. Tests are most effective when they are made according to an organized program. Your use of these tests allows detection of a substandard operation almost as soon as it appears or possibly before a unit fails.

12-5. Remember—make certain that the trouble exists in your system equipment and not in the central office equipment or in the incoming line before attempting to test for troubles in the key equipment. After having localized the trouble, you should visually inspect the wiring and connections; then if your careful visual inspection fails to reveal the trouble, you may need to use metering type test equipment to pinpoint the defective component. By following the circuit while using a systematic process of elimination, you can usually find the fault in a minimum of time. This procedure eliminates in sequence the good circuit parts.

13. Repairing Key System Equipment

13-1. You will find that just your regular maintenance of the equipment can cause a need for repair. To illustrate, each time a cover is removed to make an inspection, dust can settle on the underlying devices. Also, every time you swing the equipment gate to observe or clean the terminals at the rear of the KTUs, the single-strand wires are flexed and bent. In time, therefore, some of these wires may break. Furthermore, personnel cleaning the area may cause trouble by letting scrubbing water splash on connecting blocks or soak cable runs. Maintenance performed carelessly causes more harm than good.

13-2. Discounting the human element and assuming that all precautions were observed when the equipment was installed, there are few troubles because, with the exception of the rotary switch and the relays with their armatures and contacts, there are few moving parts in the equipment. Of course, the telephone has the PICKUP, HOLD, and CRADLE switches, in addition to the dial.

13-3. Lamps may burn out. A sudden overload may open a fuse. On extremely rare occasions a relay winding, resistor, or capacitor may become defective, but most of the actual equipment troubles will be caused by mechanical failures, for instance that of relay contacts.

13-4. **Relay and Switch Maintenance.** We know that you cannot become an expert in the care of relays and switches without making actual adjustments, but you can learn of the relay construction and can analyze the effects that a change in adjustment will have on the telephone circuit. Remember: Deviation from established values are to be expected. The manufacturer realized that the equipment adjustments would deteriorate following many operations, and he allowed for the change. Accordingly, the manufacturer's specifications generally give two sets of tolerances: one set is referred to as the inspection (test) value and the other is called the readjust (or adjustment) value. The inspection values allow for equipment deterioration before any adjustment is necessary. When you think a circuit is defective because of a relay being out of adjustment, it will be necessary that you remove the relay from the circuit in order to make the electrical test while using a current-flow test set. But this procedure should be the final action that you take.

13-5. *Relay maintenance.* You have learned that relay adjustment is divided into two major classifications: electrical and mechanical. The electrical adjustment consists of applying current to the relay. This current is similar in value to that which the relay has under actual operating conditions. Use the test current requirement for this test. If the meter of the test set registers within the prescribed range, no further check is made. If the relay is found to be out of adjustment during the current requirement test, then the controls of the current-flow test set are repositioned to permit a check of the relay using the readjustment requirements. These readjust requirements are more critical; thus less tolerance is permitted in the relay adjustments. The mechanical adjustments are corrected so that the relay can meet its electrical requirements. The mechanical adjustment consists of spring gauging, tensioning, contact spacing and alignment, and aligning the mechanical parts of the relay. Normally, an electrically readjusted relay will hold its adjustment for a considerable length of time.

13-6. Electrical requirements cannot be met without the relay having the proper mechanical adjustments. To illustrate the meaning of the preceding statement, look at figure 51 and consider the statements which

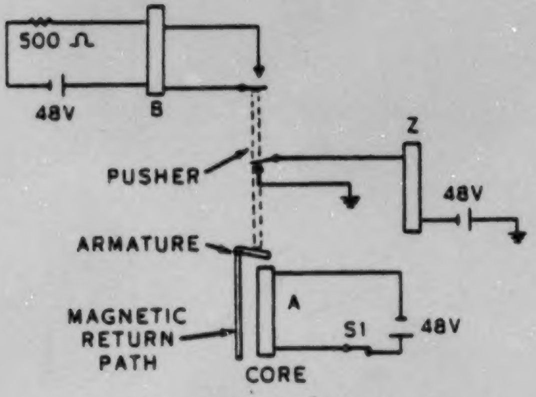


Figure 51. View of operating relay action, simplified.

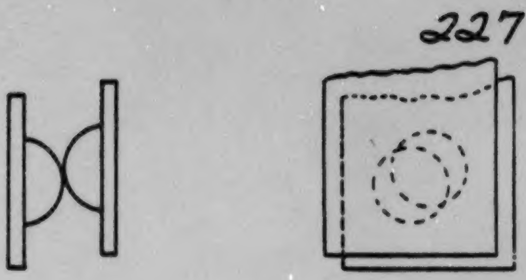


Figure 52. Relay contact alignment.

follow. You can see with this simple representative A relay, that two circuits are under the control of the A relay circuit. Since switch S1 is closed, relay A has operated and it, in turn, operated relay Z and restored relay B. Assume, now, that the make-lever spring for relay A (the spring which has forced the attached contact to complete the Z relay circuit) is normally adjusted to a tension of 17 grams as read with a gram gauge and that the break-lever spring (the spring above relay A which opened the B relay circuit) is normally tensioned for 30 grams of pressure. With these spring tensions and with the normal conductor resistance in the operating circuit of relay A, the current in the A relay is 15 milliamps. Likewise, consider that the repairman has inadvertently wiped the break-lever spring until the tension became 17 grams. Hence, the A relay operates with a reduced current; possibly 10 or less milliamps. With the reduced current, the relay operates prematurely. Consequently, relay Z operates before it should and relay B releases early, too. Think of relay A as being in the dialing circuit. How will its early operation affect the selection of a station? The result could be a wrong number. The two associate circuits are equally important; thus each must operate and release at the proper time.

13-7. The contacts, which should mate, should have adequate space between them when they are open, to insure no physical connection. Yet the space should not be so excessive that they cannot mate and then rub together (called contact follow) for an instant. This contact adjustment is not normally considered as critical as the spring tensioning or armature travel adjustments, since it has a direct bearing on one circuit only; whereas the other two adjustments could affect several springs and contacts, which in turn could affect their associated

TABLE 1
RELAY ADJUSTMENT REQUIREMENTS

Relay Desig	Coil Resist	Mechanical Requirements			Hold	Direct Current in Amperes				Remarks
						Test		Readjust		
		Contact Pressure	Arm. Travel	Resid Screw Height		Oper	Non-Oper	Oper	Non-Oper	
T	815		0.026			0.015	0.0052	0.0144	0.0054	
C	136		0.026		0.0249	0.0495	0.0213	0.0476	0.0222	1/16 sleeve
B	815		0.026			0.0157	0.0098	0.0151	0.0102	
A	60/60		0.022					0.019	0.016	Dial relay make on 0.007", break on 0.011". Test values same as readjust.

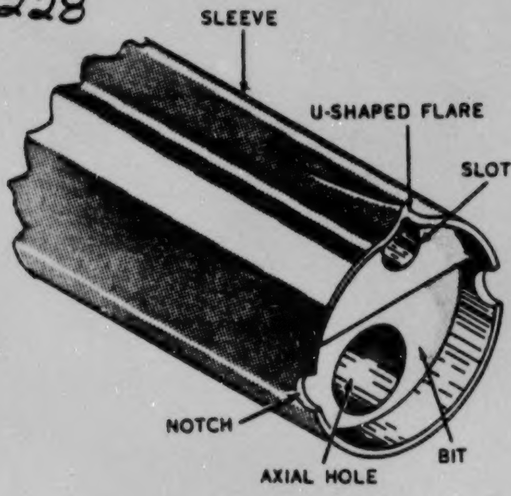


Figure 53. Closeup view of tool bit.

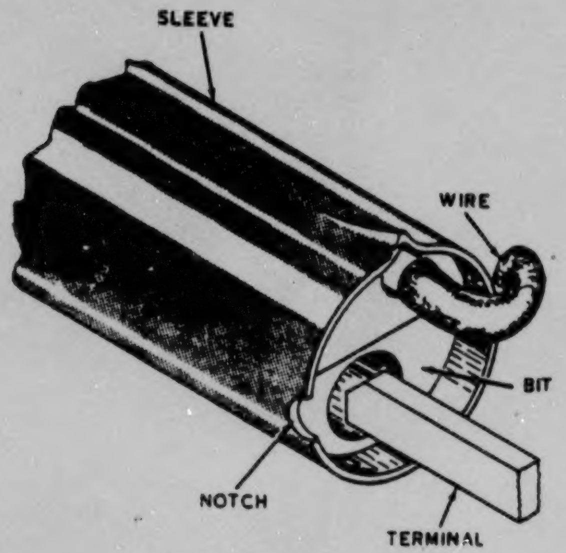


Figure 55. Closeup end view of wire and terminal in tool bit.

circuits. For the greatest possibility of accurate mating, the contacts should meet near the center but the contact positioning shown in figure 52 is acceptable to most Air Force telephone system repairmen.

13-8. Table 1 is an adjustment table which one manufacturer provided for their intercom KTU. You should have no trouble determining the requirements from this table because each column is identified. For example, the T relay has 815 ohms of resistance; its armature travel must be twenty-six thousandths of an inch, as checked with a relay feeler gauge; and the electrical test requirement is 15 milliamps of current to operate the relay. Similarly, when the current is reduced to 5.2 milliamps the relay must not operate. Furthermore, the current requirement for the readjustment test is 14.4 milliamps to operate relay T, and 5.4 milliamps should not operate the relay.

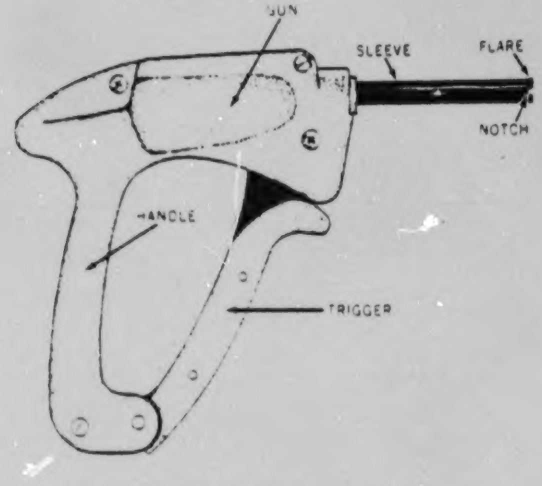


Figure 54. Wire wrap gun.

13-9. NOTE: If the time comes when you must adjust a relay, make sure that you use the adjustment table for your equipment because each manufacturer uses different specifications to accomplish the same purpose. You may never adjust your key system relays because they are reliable. For this reason, your organization may not be authorized a current-flow test set, without which you cannot make such adjustments.

13-10. *Switch maintenance.* The basic purpose of switch maintenance is also trouble prevention rather than trouble clearance. Thus, you inspect all elements of the switch at regularly scheduled periods. This inspection may often consist of a visual check only. If a switch appears to be operating improperly, adjustment may be required to restore it to full operation. We repeat, however, that you do not readjust any switch unless it is definitely at fault and must be tested electrically. You should realize from this former statement that the test of switches compares to the test for relays. Both units are tested electrically and adjusted mechanically. Since we described the relay test procedures and adjustment, we are not going into the details of switch adjustment.

13-11. We have said that the occasion may come where you need to replace a component because of a defective winding. With most

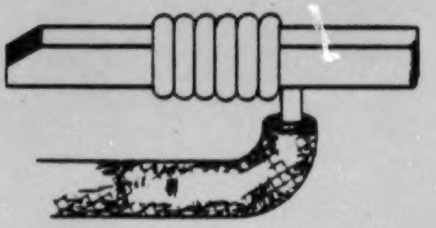


Figure 56. A completed solderless connection.

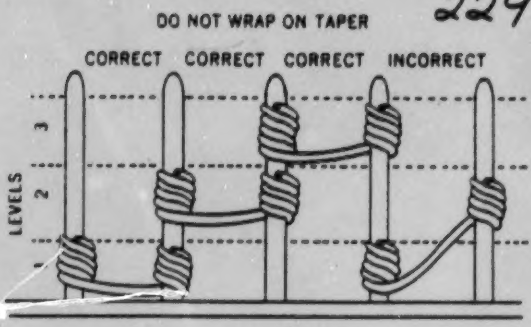

DO NOT WRAP ON TAPER
CORRECT
CORRECT
CORRECT
INCORRECT
LEVELS
1
2
3

Figure 58. Straps between solderless terminals.

systems, however, you will replace the KTU to restore the system to normal operation. Of course, replacement of a 1A2 key system KTU is simple since each KTU has contacts formed into a plug, which you then insert into its mating receptacle. The most difficult procedure requires that you remove the component. Removal is difficult because you must use a soldering iron to disconnect wiring and must identify each wire so that it is put back to the correct terminal during the component replacement. It is easier to remove the component while the KTU is installed than to take the KTU from the cabinet and then remove the component. If you remove only the component, you can leave all the unit strapping and jumpering and remove only the wires that serve the defective device. However, you must use extreme care so that you don't damage other wiring.

13-12. Key Station Maintenance. Your knowledge of telephone station maintenance also applies to key system station equipment. Although there are more mechanical devices for a key system station, you will find that the repair is comparable. Hence, we need not repeat what has been said.

14. Key System Repair

14-1. Using a Wire Wrap Gun. You may be responsible for replacement of components that are installed without using solder. The wire is connected to the terminals of these components with a tool referred to as a "wire wrap gun."

14-2. In this situation where the component is defective, you remove the wrapped wire with an unwrapping tool. You should not reuse the twisted wire again because it will probably break during a rewrap. Furthermore, you cannot get the desired pressure of the good metal-to-metal contact again. You should cut the old wrap and use the slack in the wire or use a new length of wire. However, if you must use the old wrap, solder the connection after installing the wire again. The preferred method is that you install a new wire wrap around the component terminal.

14-3. Figure 53 shows a view of the tool bit for a wire wrap gun. The axial hole is large enough to permit the tool bit to be placed over the terminal for the component being installed. You can see a slot that extends along the length of the bit. The wire to be

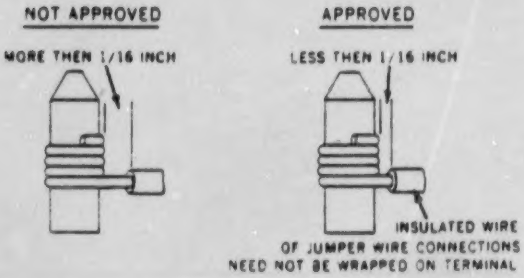

NOT APPROVED
MORE THEN 1/16 INCH
APPROVED
LESS THEN 1/16 INCH
INSULATED WIRE OF JUMPER WIRE CONNECTIONS NEED NOT BE WRAPPED ON TERMINAL

Figure 57. A solderless wrap.

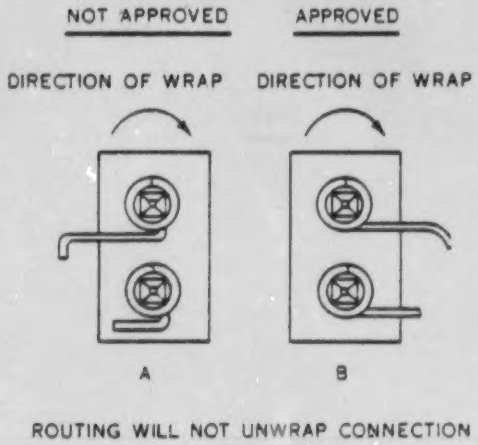

NOT APPROVED
APPROVED
DIRECTION OF WRAP
DIRECTION OF WRAP
A
B
ROUTING WILL NOT UNWRAP CONNECTION

Figure 59. Wrapping solderless terminals.

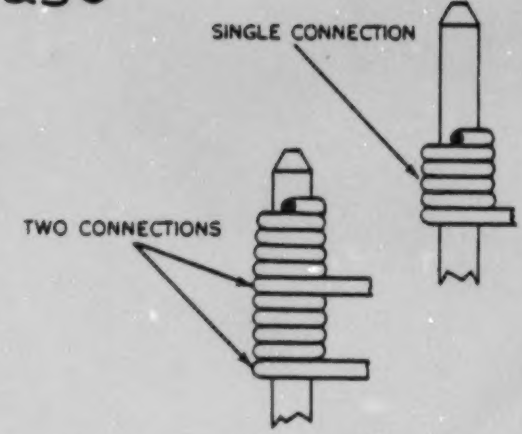


Figure 60. Single and double solderless wraps.

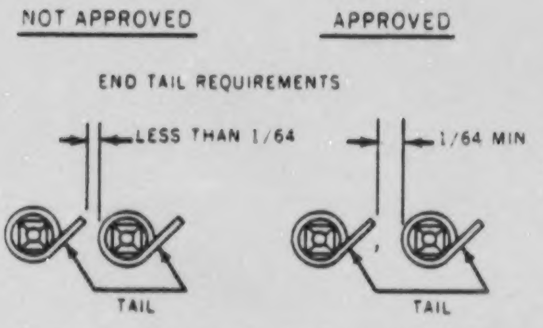
wrapped around the terminal is inserted into this slot. Figure 54 illustrates a wire wrap gun and the tool sleeve which fits over the tool bit. Figure 55 is a closeup view of the ends of the tool bit and the inclosing sleeve. The flare of the sleeve allows you to insert the wire into the slot of the tool bit more easily. The notches of the sleeve hold the wire in position while the bit wraps it onto the terminal.

14-4. Although there are several methods for powering the tools, each unit causes the bit to rotate while the sleeve remains fixed during the tool operation. Figure 54 identifies the trigger for starting the wrapping operation.

14-5. A solderless connection made with a wire wrap gun will have the basic requirements for an electrical termination. They are: Metal-to-metal contact, gastight, mechanical stability, a minimum of vibration strain and handling stress, and high-pressure contact. To illustrate, a wire wrap on a terminal has approximately 29,000 pounds of pressure per square inch. Additional advantages to wire wrap connections include: Work area is safe because there is no heat which can cause burns or no molten metal which can cause undesirable electrical connections following splashing or dripping. Also, the installation cost is reduced because you have no need for solder, and each connection usually takes less time (and therefore less money) to make than will a soldered connection.

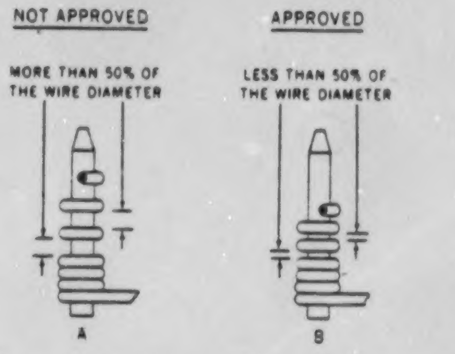
14-6. Figure 55 illustrates a wire and terminal (partially in position) at the tool bit. It is evident that most of the wire is inserted in the slot and that the insulation near the skinned wire extends through a sleeve notch. The length of the skinned wire is determined by the gauge of the wire. For example, 22-gauge wire should have 9/16 inches of insulation stripped from the wire. You must also have a minimum of skinned wire showing because the final appearance of the connection should have a maximum of 1/16 inch between the wire insulation and the terminal. Figure 56 illustrates a properly connected wire wrap.

14-7. Having inserted the wire in the slot and bent it back within the sleeve notch, you place the tool over the terminal and pull the trigger. However, make sure that the terminal used is designed for wire wrap, that the terminal is tinned (cleaned thoroughly), that the wire remains fully inserted, and that you let the tool back away slightly during the operation. Also, you must insert the tool over the terminal a sufficient distance that will allow the proper number of turns to be made. Accordingly, you must provide five or more



THERE ARE NO OUTSTANDING TAILS ON THE LAST TURN THAT COULD CAUSE A NEAR SHORT CONDITION

Figure 61. Approved spacing between two wrapped terminals.


NOT APPROVED
APPROVED
MORE THAN 50% OF THE WIRE DIAMETER
LESS THAN 50% OF THE WIRE DIAMETER
A
B

GAPS BETWEEN ADJACENT TURNS DO NOT EXCEED.
1/2 THE WIRE DIAMETER EXCLUDING FIRST AND LAST TURNS
SUM OF TOTAL GAP SPACE MUST NOT EXCEED ONE WIRE DIAMETER

Figure 62. Turn spacing for solderless wraps.

turns on the terminal when using 22-gauge wire. Figure 57 shows five turns of wire on the approved terminal connection.

14-8. When the wrapping procedure is completed and the trigger released, you remove the gun with care so that you don't bend, twist, or scrape the terminal. You will not damage the equipment if you withdraw from the terminal while holding the gun at the same angle as the terminal is positioned. Therefore, if the terminal rests with the tip up as shown in figure 57, you lift the gun straight up. If you have a terminal positioned at the horizontal angle, as pictured in figure 56, you are required to withdraw the gun straight back (toward the left).

14-9. In addition to having the wire requirement of 1/16 inch from the terminal and the minimum number of turns, you also have several other rules to observe. Figure 58 presents three. There are three levels to each terminal. You make the first attachment at level 1 and close to the base, and continue your wrapping at level 2, then you use level 3. Furthermore, you must form all straps at the same level. Note too that you must leave some slack when strapping terminals. The instructions above the terminals of figure 58 show that you must never wrap at the very tip of the terminal because it tapers, thus will prevent your making a quality connection. Wrap the wire on the terminal in a manner that will prevent its being unwrapped during your further routing of the wire. Figure 59 may help you visualize this procedure. The connection of 59,B, shows that the wrapping direction is clockwise and the wire routing continues to the right of the terminal. The wire of A in figure 59 implies that you are routing it to the left after having used a clockwise wrap. When wrapping two or more levels on the same terminal, you must never overlap any turn. Of course, you also must never overlap any wire turns with the single wrap either. Figure 60 illustrates this requirement for terminals having single and double connections. To prevent an undesirable connection (short) between two terminals, make sure that you remove excessive pigtail from the last turn. Figure 61 shows 1/64 of an inch of space between the pigtail of the left terminal and the wrap on the right-hand terminal. Figure 62 illustrates the spacing requirement between turns. Hence, the maximum gap is the diameter of one wire. It is evident in figure 62,A, that the total distance of the two diameter of the wire; whereas the spaces in figure 62,B, total less than the diameter of the wire. If the gap is excessive, remove the wrap, cut off the twisted section of the wire, and make a new wrap.

14-10. Replacing Wiring. We noted that most troubles are the result of moving elements. Therefore, broken wires in a cable are not often found. This is a good thing, because it is difficult to locate a broken wire in a cable. You could use either the jumper wire method or the resistance test (see para 12-3) to identify the faulty conductor. The probable repair for a cable having a faulty wire or wires is to replace the cable. This procedure compares to the cable installation which we have described in a former chapter. If replacement straps are required between terminals, form them in the same manner as the one to be removed. Use care that you remove only the amount of insulation required because excessive bare wire can cause short circuits. Short, bare cross-connecting wires are permissible where there is no danger of short-circuiting with another circuit (see fig. 58). Otherwise, insulated straps (jumpers) of the proper length must be used. The method used to terminate the wire is determined by the terminal. If soldering is required, skin the insulation from the wire; clean the wire to insure a good connection before soldering.

14-11. We can summarize this chapter by saying that your troubleshooting procedure should consist of the operation of the equipment for verification of trouble, analysis of circuits to isolate the unit in trouble, visual inspection of apparent defective units, a point-to-point check using test equipment, and after replacement or repair of unit, you again operate the equipment. Remember: Communications equipment functions best when it is not "manhandled." In other words, do not touch any part of the equipment unless the system is definitely failing to perform the service expected. When operational tests disclose a definite need for corrective maintenance, think, and then do the trouble location and repair in a systematic manner.

CHAPTER 5

Intercommunications Systems

IN THIS CHAPTER we expect to repeat some statements of the previous chapters. So you should realize that these statements are of special importance to an installer-repairman. At the same time, a principle which you may not have fully understood before may now become clear when used in a different circumstance. Too, new thoughts will be introduced. We expect you to add them to your memory for your future reference when working with intercommunications equipment.

2. We have already briefly discussed Air Force intercommunications systems. We learned that although the Air Force uses equipment manufactured by a number of commercial organizations, the operating and installation principles are similar.

3. To make our discussion of this chapter more meaningful, we will describe the installation, operation, and repair of a system having two master and four remote stations and they will have the nomenclature 224M-9 and 224AM-3-9 for the master stations and 5A45 (LS-129/F1) and 5A45B (LS-130/F1) for speaker-microphone units at the remote stations.

15. Planning an Intercommunications System Installation

15-1. We learned that there are several makes of intercommunications sets. The older sets have amplifiers consisting of vacuum tubes, whereas the recent sets use solid-state components. Of course, the older style sets can still be in production today. Vacuum tube amplifiers and power sources result in larger sets. Yet, even the larger sets will vary in dimensions. For example, the master sets illustrated in figure 63 are stations manufactured by one company. Although their appearance is similar, they differ in station capacity, type of power source, or accessories. Thus, just as with automobiles produced by one company, each model differs from another in many ways.

15-2. When you plan a system installation, you must be able to distinguish between the various models. Each company simplifies this ordering by using coded model numbers. You should recall that the key system manufacturers also use a coding system with their telephones. Using the model 224AM-3-9 of figure 63 as an example of a coded number for the Webster Electric Company, we will identify the station. The prefix 2 is standard for all of these models and, as a result, all are spoken of as model 206, or 212, or 224. The 24 of our example identifies the station as having 24 selector keys; thus, it has a station capacity of 24. NOTE: This 24-station capacity enables it to serve 23 remote stations and 1 additional master station, or 22 remote stations plus 2 master stations, or any other arrangement that totals 24. The AM in the coded number denotes that the set is equipped with annunciators and is a master station. The suffix -3 of our code number designates that the master station is equipped with three position selector switches (keys). The -9 indicates the operation of a switch that controls the impedance of the unit. One position of this switch selects 50 ohms for the impedance and the second position connects 500 ohms as the unit impedance. It is evident that each illustrated model in figure 63 permits this impedance to be changed. Any station having a model number that does not include the -9 has a fixed impedance of 50 ohms. Using this pattern for coding the model number, we can deduce that the 224M-9 master station has 24 selector keys and can be used with a circuit requiring 50 or 500 ohms of impedance. However, it does not have annunciators, and the selector keys have only two positions. The DOWN position for operating annunciators at remote stations is not provided.

15-3. The planning used with a key system

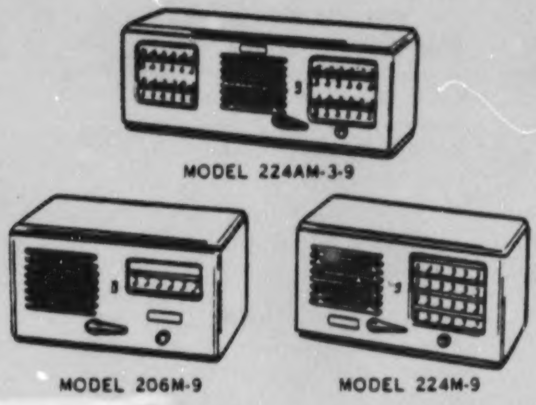


Figure 63. Intercommunications sets.

also applies to your preparation for the installation of an intercommunications system. Consequently, your well-planned installation requires few changes and a minimum of repairs. Of course, you must know the requirements of the requesting agency in order to select the equipment that will provide the desired service. Thus, you should know the number of stations to be installed, the proposed location of the stations (whether exposed to moisture or excessive noise, or if to be placed in a hazardous location, etc.), the status of the organization (whether it is an organization requiring extreme security measures, or if the organization is expected to require additional stations in the future), and the distance between stations and total length of the cable loop. In addition, you should know the position of other communication system

Terminals	UNIT					
	224M-9	LS-129/FI	LS-129/FI	224AM-3-9	LS-130/FI	LS-130/FI
#1	Blue	Brown	Orange	Blue	Green	Slate
	White	White	Black	White	White	Red
				Strap		
#2	Orange			Orange	Violet	Violet
	White			White	Yellow	Yellow
#3				Green		
				White		
				Violet		
#4	Brown					
	White					
#10				Slate		
				Red		
				Violet		
#12	Orange			Orange		
	Black			Black		
#13				Strap		

Figure 64. Interconnection sheet.

cables because intercommunications cables placed close to other cables can induce noise into each other. It may be necessary that you order shielded cable to reduce this induction probability.

15-4. To satisfy the using agency, you plan, install, and inspect carefully. You saw cut sheets that were used as planning guides in a key system and as the standard for your installation. Your intercommunications installation will also be most effective when you use some form of interconnection diagram chart or sheet.

15-5. **Using Installation Diagrams, Charts, or Sheets.** Since the installation problem for an intercommunications system is usually simple when compared to telephone, key, or other communications systems, the manufacturer may not provide an interconnection sheet as a standard for you to use. In this circumstance, an alert supervisor will design a diagram, or chart, or cut sheet which shows the connections. As a result, he, his associates, and future technicians and repairmen assigned to the organization can determine what the installation includes, how the connections were made, where they were made, what pairs are spares, and where modification has been accomplished.

15-6. A chart similar to the one shown as figure 64 could be used to identify the junction box terminal connections. According to this chart, terminals #1 for the 224M-9 have blue and white wires attached, terminals #2 for the same unit have orange and white wires, terminals #4 have brown and white, etc. To identify the connected wires at the 5A45, figure 65, we have listed them as attachments at the LS-129/F1. However, these units only have one pair of terminals. Therefore we have shown the terminals as #1. Likewise, the voice terminals of the other speaker-microphone units (LS-130/F1) are listed as terminals #1. The third and fourth wires for the slave units are shown as being connected to terminals #2 and have insulation colored violet and yellow.

15-7. **Selection of Equipment.** An intercommunications system compares with a key system in that both are constructed to provide reliability, strength, rapid installation, and some flexibility. Yet we desire some standardization in all installations, and we definitely must consider the cost of each system. Since there are many different systems, you should take all into consideration. However, you may be handicapped by a low inventory at your local community equipment source; thus you must make the selection from what is available. For our purpose, we selected the system for which there is a technical order available. It will describe installation, operational, and maintenance principles. Furthermore, we are considering only a few factors; you will undoubtedly find others that affect your selection.

15-8. If the using organization requests two master and four remote stations, then you will take that into consideration. Yet, we should not purchase a system limited to 2-4 stations if the organization is expecting a future expansion of the system. A low-cost purchase of a limited size system would result in false economy. Obtain a system, in this case, which is designed to permit expansion. If a remote station is to be placed where it is exposed to moisture, then you should select a

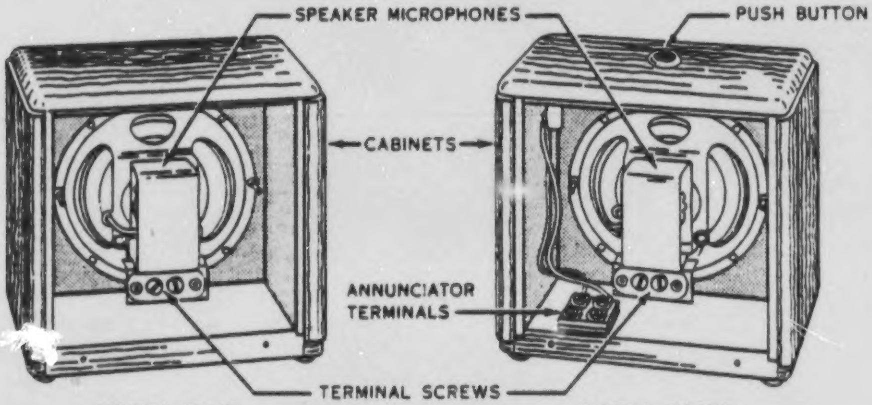


Figure 65. Speaker-microphone units.

moistureproof unit. Likewise, if the proposed location is a noisy area, you should make provisions for service there. A hazardous area may require an explosion-proof station. We said that our selected system requires an impedance of 50 or 500 ohms. You will also have to make allowances for impedance when selecting your system. The distance between stations and total distance of the system loop partially determines the system impedance.

15-9. The power source available at the organization also has a bearing on your selection of a system. Usually, 50- to 60-cps alternating current will be provided. But there is a possibility that other frequencies may be provided, or your requesting agency may already have a dc source.

16. Installation of an Intercommunications System

16-1. Having completed your planning and selected your equipment, you install the equipment. The mechanics for installing a system are relatively simple. Many of the concepts expressed with regard to the key system installation also apply here. For example, the units requiring power should be located near an outlet and you should avoid placing cables or wiring near hot water pipes or steam lines because the heat may, in time, damage the insulation.

16-2. **Location Requirements.** The master station should be placed to the rear of a desk or a table where the controls are not obstructed and are, therefore, convenient for use; yet the set should be kept dry and free from mechanical or electrical hazards. Another reason for placing the station to the rear of the desk is that you then get the maximum benefit when talking into the speaker-microphone. You do not normally secure the station to the desk; thus it can be relocated easily. Where a speaker-microphone is to be mounted on a wall, position it at a height where it won't be a safety hazard; yet place it where the sound waves can strike with maximum effect. Accordingly, you may find it necessary to cut an opening in the wall and insert the unit until the face panel is flush with the wall surface. A speaker-microphone mounted in a corridor should be at least 8 feet from the floor, unless it is flush-mounted in the wall.

16-3. **Equipment Installation.** You have learned the desired location of the equipment from the work order or from the user. Also, you know the requirements for a proper placement. Therefore, you can now install the equipment. It is a simple matter to install the equipment for a small system because you need only to attach the speaker-microphone to the wall with the brackets and fittings provided or set it on a table, and place the master station on the prescribed desk. Power connections are not required at the slave stations because they get their power from the master stations. Extend the power cord of the master station to the power outlet, but do not plug it in. In some offices you may have to make arrangement during your planning to have another power outlet provided near the selected desk because it is not a desirable practice to use extension power cords. When large systems are installed, you may be required to mount terminal cabinets which have connecting terminals or blocks. Bridging terminals already described could serve this function too. These terminals serve as central cross-connecting points for cables connecting the master stations together and for cables connecting together the master stations and the slave stations.

Size Wire	Resistance Per Pair
No. 22	32 ohms per 1000 ft.
No. 19	16 ohms per 1000 ft.
No. 16	8 ohms per 1000 ft.
No. 14	4 ohms per 1000 ft.

Figure 66. Wire resistance table.

16-4. **Cable Installation.** When installing an intercommunications system, you must consider certain transmission limitations that are peculiar to each system. To illustrate, you know that this system that we are describing has an impedance limitation of 50 to 500 ohms for the voice circuits. Figure 66 makes it evident that the length of the loop and the gauge of the wire determine the impedance for the voice circuit. For example, this figure shows that a 1000-foot section of 22-gauge paired wires provides 32 ohms of resistance. Consequently, you could not extend the circuit to 2000 feet while using 22-gauge wire if the stations are selected for 50 ohms of impedance. Yet, by using 19-gauge wire for your voice circuit, you could separate the stations by 3000 feet. Remember: The use of long voice loops will affect the voice pickup coverage of the speaker-microphone.

16-5. Intercommunications system voice pairs are not to be included in a telephone cable because the higher frequencies and volume of amplification in this system may induce voltage into the telephone circuits, thus resulting in crosstalk. A similar precaution should be observed concerning these voice pairs and high-voltage powerlines. The high-voltage lines can likewise induce a hum (noise) into the voice circuits. It is, therefore, a good practice to keep a 1-foot separation between intercommunication circuits and other lines. Of course, we know that shielded cable or lead-covered cable limits these induction problems, but the additional cost for this type cable must be considered when planning your installation. A shielded cable must also have its sheath connected to ground, preferably near the center of the cable.

16-6. When it is necessary to ground the master station because of excessive noise, replace the power cord with a three-conductor cord equipped with a three-prong polarized plug. If such a plug cannot be used in the power outlet provided, obtain a three-wire plug adapter to connect the power cord to the outlet. Terminate the ground strap on the plug adapter under one of the screws with which the faceplate is secured.

16-7. You must also consider the wire size when installing the annunciator circuits. Loop resistance for these signaling circuits must be less than 15 ohms.

17. Operational Testing of Intercommunications System

17-1. The operations that we describe will probably vary from the procedures which your equipment requires, but again we stress that the principles are comparable. Think of the results that you expect from your system and the methods for providing them!

17-2. The checkout of an intercommunications system is done in much the same manner as was the key system test. Remember: You must check each station for all of its operational functions.

17-3. You can use a helper in checking the stations of an intercommunications system. The following procedures describe the test for our representative system:

a. Plug in the power cords at the two master stations.

b. Turn the combined volume control and ON-OFF switch until you hear a click and observe the pilot lamp. The lamp operates when the equipment is ready to function.

c. Select the desired station by moving the associated selector key up (ON position).

d. Monitor the desired circuit to determine if it is busy. You do this by listening at the speaker while keeping the TALK-LISTEN switch in the IDLE position.

e. Turn the volume control to increase the volume.

f. Press the TALK-LISTEN switch to the TALK position if no conversation is heard.

g. Talk into the speaker-microphone while keeping your mouth about 12 to 18 inches from the front of the unit. Talk in a normal, distinct manner.

h. Release the TALK-LISTEN switch to the LISTEN position and prepare to turn the volume control toward the desired level of strength.

i. Listen for your helper's response and adjust the volume, if need be.

j. Reply while reoperating the TALK-LISTEN switch to the TALK position.

k. Return the TALK-LISTEN switch to the IDLE position and the selector switch to the OFF position.

l. Rotate the volume control to the OFF switch position and observe the pilot lamp. It should go out.

m. Remove the power plugs from the wall receptacles.

17-4. In many cases you will have additional signal circuits to test. You test the signal circuits as follows:

a. Plug in the master station power cord.

b. Turn the volume control to the ON switch position.

c. Depress the selector switch to the SIGNAL position.

d. Release the selector switch to the OFF position.

e. Press the selector switch to the ON position.

f. Press the TALK-LISTEN switch to the TALK position and turn the volume control to nearly full clockwise position.

g. Talk into the speaker-microphone and ask the helper to comment about the signaling results.

h. Release the TALK-LISTEN switch to the LISTEN position.

i. Reoperate the TALK-LISTEN switch to the TALK position and request your helper to press his signal button in an effort to operate this station's annunciator and buzzer.

j. Return the TALK-LISTEN switch to the IDLE position and the selector switch to the OFF position.

k. Listen for the buzzer to operate and look for the annunciator plunger to pop out.

l. Following the signal, lift the selector switch, restore the annunciator plunger, and operate the TALK-LISTEN switch as described previously. NOTE: If the helper is at a master station, you do not operate the TALK-LISTEN switch to the TALK and LISTEN positions. The IDLE position allows your station to function as if it were a speaker-microphone unit. You simply answer the helper when he speaks. If two master stations provide amplification at the same time, you will often have speech distortion or noise.

m. Advise your helper to proceed to the remaining remote station and to signal this station after arriving there.

n. Return the selector switch to the OFF position and the TALK-LISTEN switch to the IDLE position.

o. Await the signal from the helper.

p. Then, test that station's circuits as described above.

q. Insure that the selector switches are in the OFF position, the TALK-LISTEN switches are in the IDLE position, and that the annunciator plungers are restored.

r. Turn volume control to OFF switch position.

s. Pull the plug of the master station from the wall receptable.

18. Intercommunications System Maintenance

18-1. AFM 39-1, *Airman Classification Manual,* states that the telephone installer-repairman is responsible for the external wiring of interoffice equipment. Thus, he makes minor repairs or replaces defective wiring between stations. If trouble is not in the wiring portion of the interoffice equipment, he will make note of the trouble in the set itself and will inform the radio maintenance personnel of the difficulty. To be able to do this, the telephone installer-repairman may be asked to perform routine inspections on the equipment, isolate faulty wiring, locate troubles, and make minor repairs.

18-2. Routine Maintenance. To insure the efficient operation and uninterrupted service of any intercom system, various inspections or checks of the equipment are necessary. The daily and weekly checks are made by operating personnel, and the monthly checks should be made by a repairman. Occasions may arise, however, when you will be called upon to show master station operators the correct procedure for making these daily and weekly checks of the equipment.

18-3. *Daily checks.* At the start of each operational day, the operator should:

a. Be sure that the master station is positioned for convenient operation with the controls unobstructed.

b. Wipe dirt and moisture from the cabinet and controls, using a clean, dry cloth.

c. Operate and restore each station selector switch, TALK-LISTEN switch, and volume control. There should be no binding, scraping, or excessive looseness.

18-4. *Weekly checks.* Once a week the operator should:

a. Inspect the cabinet for cracks, scratches, and corrosion.

b. Inspect the controls for cracks and nicks.

c. Inspect the junction box cable and power cable for kinks, cuts, and fraying or deteriorated insulation.

18-5. These checks may, on the surface, appear to be minor and unimportant, but you should keep in mind that dirt and moisture inside the set and in the controls are often the cause of equipment failures.

18-6. *Monthly checks.* Once each month, at regular intervals, the telephone installer-repairman should:

a. Remove the chassis and inspect the pilot lamp, fuse, and tubes for proper seating. Do not withdraw the vacuum tubes from their sockets; check only for looseness.

b. Check the controls to be sure that they are not loose in their mountings and that they operate with a positive degree of action without scraping or binding.

c. Tighten all loose switches. Be sure that the impedance switch setting has not been changed.

d. Inspect the cabinet, chassis, and junction box for scratches and moisture. In addition, inspect all metal surfaces for rust and corrosion.

e. Inspect the power cable, junction box cable, chassis wiring, junction box wiring, and cabinet wiring (if any) for cuts, breaks, fraying or deteriorated insulation, kinks, and strain at the terminals. Inspect for twists.

f. Inspect all electrical parts for looseness.

g. Inspect the terminal boards in the junction box for cracks, dirt, grease, and loose connections.

h. Inspect the vacuum tubes to be sure that the envelopes are not loose or cracked. Inspect the tube socket for cracks.

i. Inspect all capacitors for leaks, bulges, and discoloration. These symptoms will often indicate trouble in the unit.

j. Check resistors for cracks, chipping, blistering, discoloration, and loose connections. Check connections for corrosion and dirt.

k. Check solid-state devices for cracks, chipping, blistering, discoloration and loose connections.

l. Inspect transformer mounting screws for looseness. Before leaving the equipment, be sure that all connections are secure. Look also for blistered paint on a transformer.

m. If the unit has been moistureproofed and fungiproofed, check all connections for this proofing.

18-7. **Isolating Faulty Wiring.** As with all communications circuits, faulty connections and wiring are often difficult to determine. You may be advised to install new wiring rather than spend the time searching for a suspected trouble. If location of the trouble is required, you must know the wiring plans and understand methods for identifying defects. We know that a useful identification method is visual observation. The visual inspection permits you to locate loose connections and broken wires. Permanent troubles such as short, grounded, or crossed circuits may require you to use test equipment in order to locate the trouble.

18-8. When trouble is reported by an operator, consider the possibility of a mistaken procedure. You learned the reason for making a personal performance test in Chapter 4. After eliminating the operator as the possible cause, you determine whether the fault is internal or external. You know that an internal trouble in any station is to be reported to the radio repair section for correction. The external trouble, wiring of a cable between stations, is your responsibility.

18-9. Open, shorted, crossed, or grounded conductors in the external wiring are usually indicated by trouble symptoms. For instance, the operator may not be able to signal, or the two attendants cannot converse, or there may be excessive noise while the connection is completed between two stations. To determine the circuit in trouble, you plug in the power cord and operate the ON switch. Then you operate the selector switch to ON (if testing the voice circuit) or to the signaling position. You should operate and restore each selector switch to determine if the trouble is common to all circuits or if it is isolated to only one. If hum or noise is the problem, you must determine if it is caused by electronic devices within the set or caused by the position of the wires or cable. You can isolate the faulty area by restoring all selector switches to the OFF position and alternately placing each TALK—LISTEN switch in the LISTEN position. If the noise is present with the switch in the listening position, the master station is at fault. Conversely, if the hum disappears following movement of the switch to LISTEN, then the fault is an external type.

18-10. Another symptom that may be reported by an operator is actually his own fault. In this case, the speech is distorted and noisy when three stations are connected simultaneously. The cause of this symptom is double amplification of the voice signals. Tell the reporting operators that only one master station should have the TALK—LISTEN switch in the LISTEN position for this bridged system call. All other master stations must be used as speaker-microphone units. Therefore, the operators of the second and third master stations place their TALK—LISTEN switch in the IDLE position.

18-11. **Trouble Location.** Now that we have determined the section at fault through our operational procedures and knowledge of normal and abnormal symptoms, we must locate the specific unit that needs to be changed. Considering that the abnormal symptom is noise in the external wiring, you trace the wiring and note its position. You know the results of having your wiring close to other communications lines and devices. At a suspicious closely positioned section of cable, move the cable farther away from the second system's component and recheck for noise. If there is a noticeable decrease in noise, reroute your system wiring.

18-12. After checking all wiring and finding no problems, you should make a detailed report of all symptoms to the radio maintenance personnel, who will make a thorough internal check of the unit.

CHAPTER 6

Maintenance of the 302 Switching Unit

PRINCIPLES of operation and maintenance described in the previous chapters also apply to the 302 Switching Unit. To illustrate, the depression of a key completes an electrical circuit to a relay. The relay, in turn, completes additional circuits to lamps and relays. A telephone system functions because of these devices.

2. The function and many of the devices of the 302 Switching Unit are, of course, somewhat different from those described previously. Also, this equipment includes a greater number of devices. We will show diagrams containing these devices and compare them to those with which you are already familiar.

3. An installer-repairman must understand electronic circuit principles, component nomenclature, and the equipment connecting methods for a 302 Telephone Switching Unit, if he is to be a fully qualified airman in this career field. This chapter will provide information about each of these factors. However, not all the devices, nor circuits, nor troubles are described because, as has been said before, we are naturally limited in our space. Furthermore, radio equipment circuits are not your responsibility. Your study of this chapter, in conjunction with the companion diagrams, should prepare you for your work with the equipment and the technical orders. You should gain knowledge while doing the work.

19. System Function

19-1. The 302 Switching Unit provides signaling, supervision, and communications for an Air Force operations van, aircraft, base operations, the weather station, the ground control intercept (GCI) station, and a control tower by means of wire and radio circuits. Because of these applications, the functions of the system are listed as:

- Wire-line and radio communications. (Remember: You perform maintenance on lines and circuits that connect with radio equipment, but the radio equipment is not your maintenance responsibility.)
- Request and acknowledge signaling.

19-2. **Wire-line and Radio Communications Circuits.** These circuits permit voice communications over loudspeaker or telephone units. The wire circuits include a dial, push type (nonlocking) keys, turn switches, relays, terminal boards, cable pairs, headsets, 106B loudspeakers, and telephones. A dial should indicate to you that there is a circuit to a central office or PBX line. In addition, there are station lines which permit automatic signaling from a telephone station. The radio communications circuits include a transmitter, radio equipment, and a loudspeaker. Most of the controls for the circuits are installed in the operations van. Figure 67 illustrates controls for an assistant controller's shelf. It is evident from the identification of these units that some of the controls are familiar. For example, we have already discussed LINE PICKUP keys and lamps. We also described HOLD keys at that time. For each line in this equipment, there is a HOLD lamp that is separate from the LINE lamp. Figure 68 shows a partial view of the interior of an operations van. Accordingly, it is apparent that there are three assistant controller's positions. Therefore, although only one set of controls is shown in figure 67, there are three sets of the controls in a van. The controller's OFF-WIRE-RADIO keys may not be familiar controls. They are lever type keys which lock into the selected position. Since they permit the controllers in the van to change the talking path from wire circuits to radio circuits, or vice versa, these controls are often spoken of as transfer keys. Two keys are necessary because one serves the controller's position and the second is operated by the assistant controller. In addition, a position may be unattended. At this time, the transfer key for the unoccupied position must be selected to RADIO or OFF. Another unit, shown in figure 68, is one that we also are considering with the controls because without it the communications circuits could not function. This is J53033P-1. This is a jack box unit, which accepts the plugs of the head telephone set (headset).

19-3. Station line telephone communications are possible between all system locations having a telephone. Typical locations with a telephone set are the control tower, base operations, the weather observer station, and the GCI station. The telephone in the control tower is a wall type, and with it, signaling for outgoing calls is done by removing the handset from the hookswitch. This signaling arrangement is often referred to as a "direct line" method. The GCI line provides two-way telephone communications between the operations van and GCI station or voice signaling from the GCI station to the operations van. Voice communications from the GCI activate the loudspeaker in the operations van unless one of the controllers or assistant controllers is, by chance, monitoring the line. An operated key disconnects the loudspeaker of the operations van while connecting the headset to the GCI line. The loudspeaker is centrally located so that it can be heard at each of the six positions. It is not shown in figure 68.

19-4. The FLASH AND RING pushbutton (see fig. 67) connects ringing current to the selected station line, whereas the RLS pushbutton disconnects the headset from this line. The telephone dial permits the associated station attendant to dial directly over a PBX or central office line. The number of lines is dependent on the type of equipment and organization. To illustrate, the shelf for the ground control approach (GCA) system pictured in figure 67 indicates the number of lines to be six. Other mobile radar approach control (RAPCON) systems may be larger than this one. Likewise, stationary RAPCON systems are larger. Remember: The dial provided as a part of the wall set in the control tower is not used in this mobile GCA system.

19-5. Radio communications are possible from the tower when the operator operates a PUSH-TO-TALK switch for the transmitter at his position. The controller in the van places

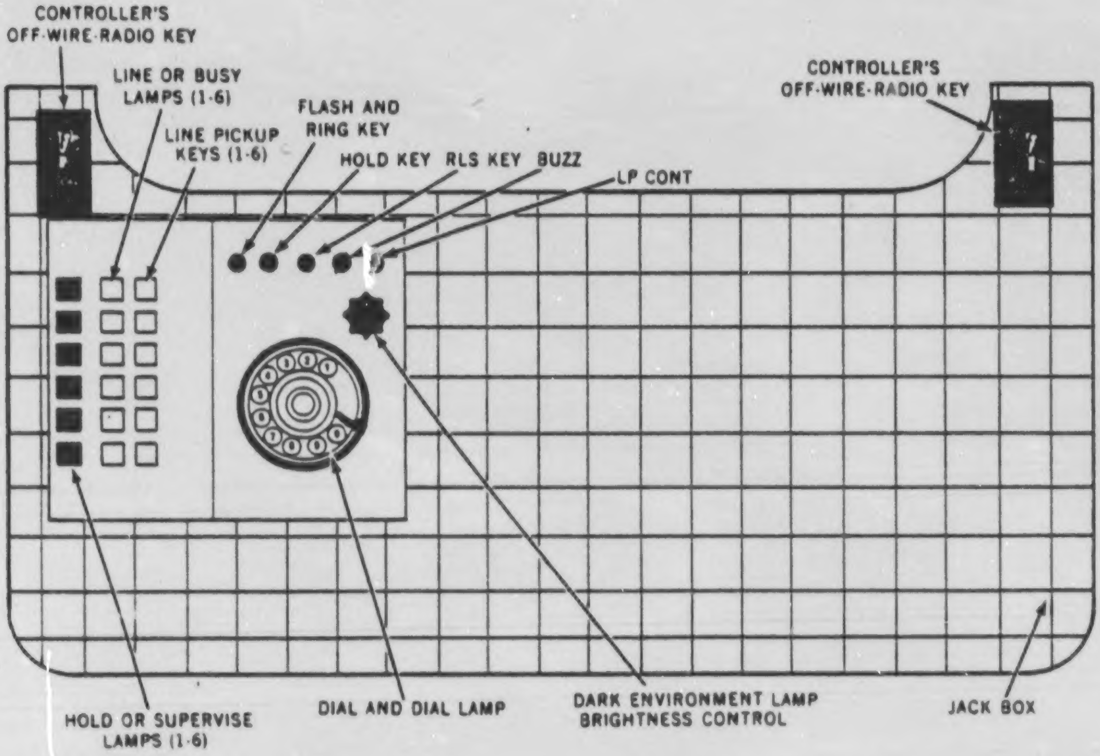

CONTROLLER'S OFF-WIRE-RADIO KEY
LINE OR BUSY LAMPS (1-6)
LINE PICKUP KEYS (1-6)
FLASH AND RING KEY
HOLD KEY
RLS KEY
BUZZ
LP CONT
CONTROLLER'S OFF-WIRE-RADIO KEY
HOLD OR SUPERVISE LAMPS (1-6)
DIAL AND DIAL LAMP
DARK ENVIRONMENT LAMP BRIGHTNESS CONTROL
JACK BOX

Figure 67. Wire-line communications controls for assistant controller's position.

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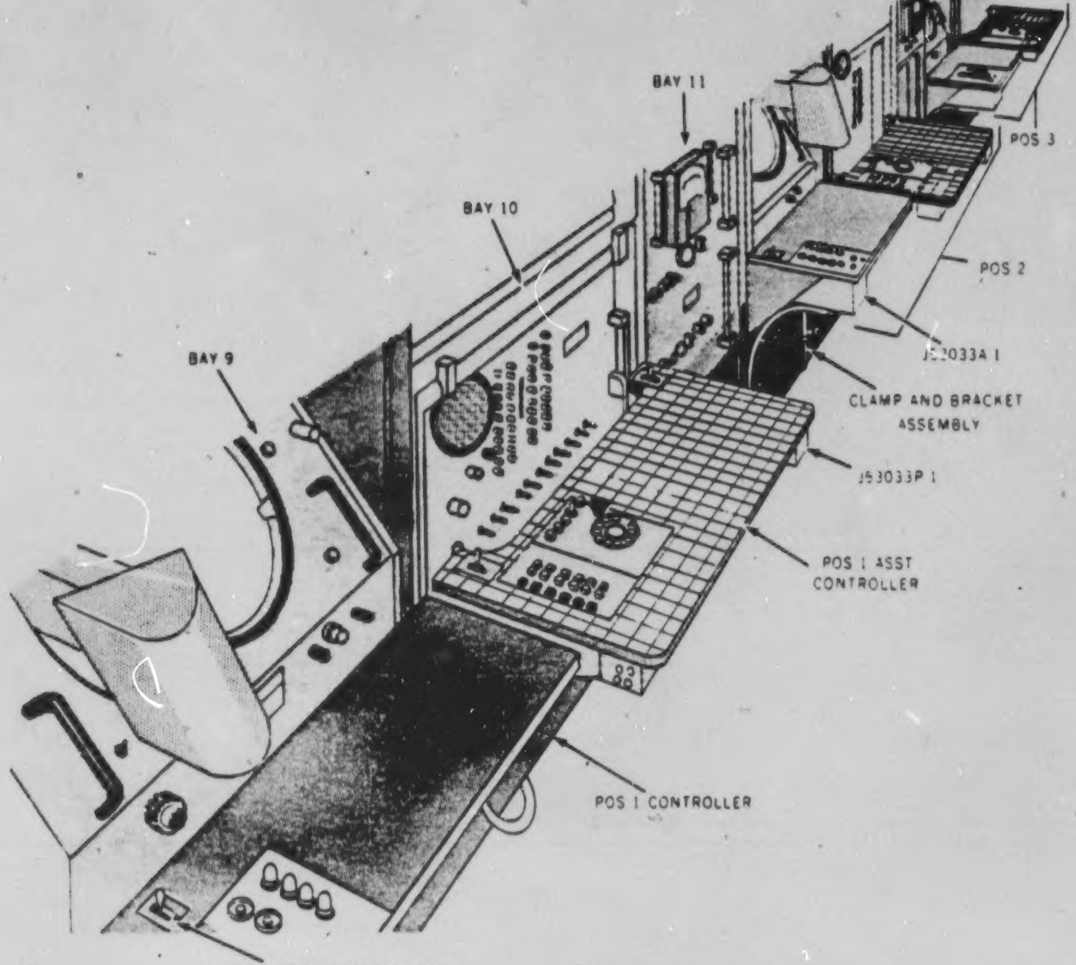

Figure 68. Position arrangement of operations van.

the transfer key in the RADIO position when speaking to an aircraft by means of radio circuits. The OFF position of the transfer key permits the controller to listen to radio calls but prevents the controller's voice from being transmitted.

19-6. **Request and Acknowledgment Signaling Circuits.** Both visual and audible signaling are provided by these circuits. The key and lamp units permit visual indications, while the loudspeakers and a chime are used for audible signaling. The controls and signal indicators for these circuits are located at the operations van and in the control tower. The operations van is identified as the "requesting station," and the control tower is referred to as the "acknowledgement unit." Three identical sets of controls and indicators are included in the operations van. Figure 69 reveals one set of controls and indicators at the requesting station. Figure 68 also shows the equipment but identifies it with a J53033A-1. Also, you can see that the equipment is installed as a part of the controller's shelf in the operations van.

19-7. The operation of the colored pushbuttons and lamps results in identification of the various phases of an aircraft landing procedure. For example, depression of the WHITE key at the operations van results in flashing WHITE lamps and in operating a one-stroke chime at the control tower. The flashing WHITE lamps indicate to the controllers at the operations van and to the operators at the tower that a plane is a specific distance from the field during the landing approach. A tower operator acknowledges by pressing the WHITE pushbutton at his position; thus the lamps at the tower and van light steadily. When the radarscope (see fig. 68) indicates that the plane has arrived at a certain position, which is closer to the landing strip, the controller depresses the AMBER key. As a result, the WHITE lamps at the van and tower go out and the AMBER lamps at both stations flash. Again, the chime at the tower sounds once. The tower operator acknowledges by pressing an AMBER pushbutton. Hence, the associated AMBER lamps glow steadily.

19-8. With the arrival of the plane at a third designated position, as indicated by the radarscope, the controller presses the GREEN pushbutton. Again, the chime sounds and the associated GREEN lamps flash while the AMBER lamps become dark. The tower operator depresses the GREEN pushbutton at his position to acknowledge. Now the GREEN lamps at each station change to a steady glow.

19-9. The RED pushbuttons operate in a manner opposite to that described for the three former keys. When the tower operator presses the key at his position, the RED lamps flash. The controller acknowledges, in this case, by pressing the RED key on his shelf. Then the RED lamps cease flashing and glow steadily. The reason for installing the RED key so that the effects are opposite to the previously operated keys is that the tower operator must be able to alert the controller when there are conditions that do not permit a plane to land. Since red is symbolic of an emergency or requires a stop in the action, we can see the reason for using a RED key and

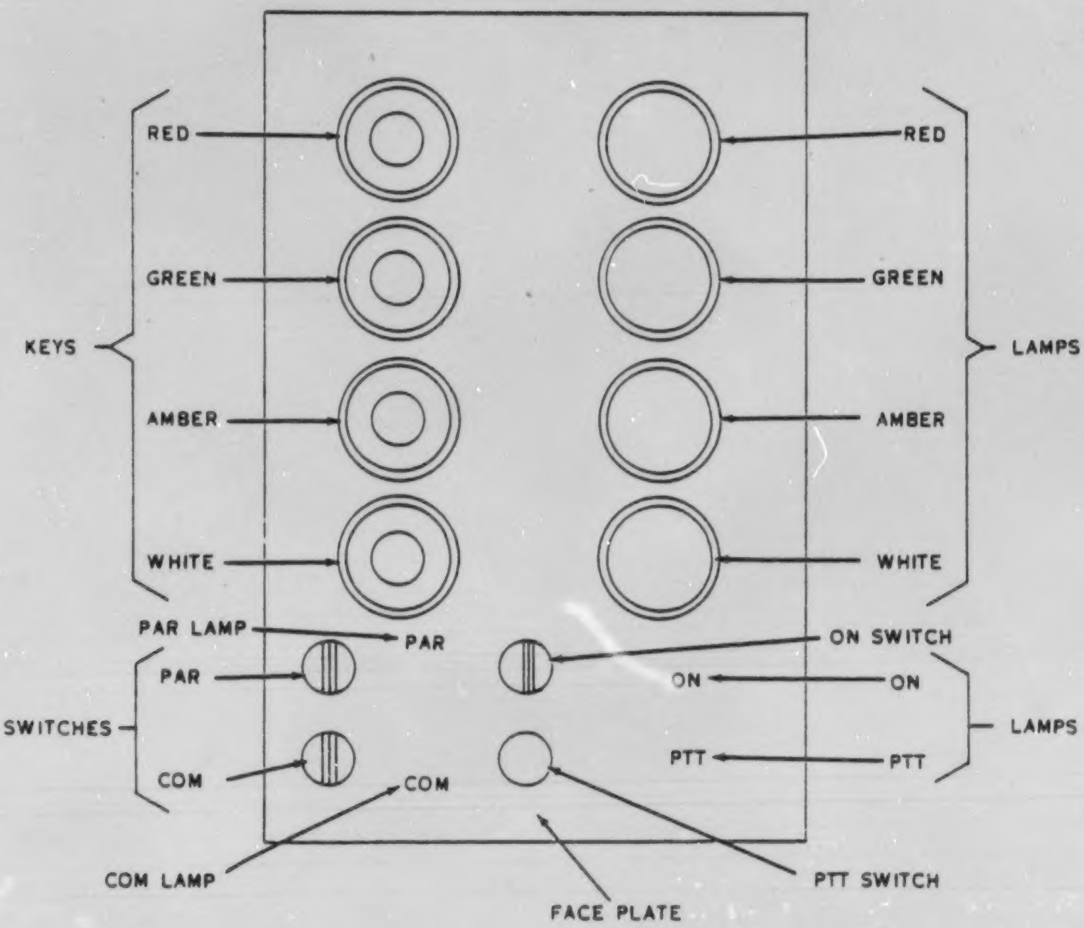

Figure 69. Closeup view of control devices at controller's position.

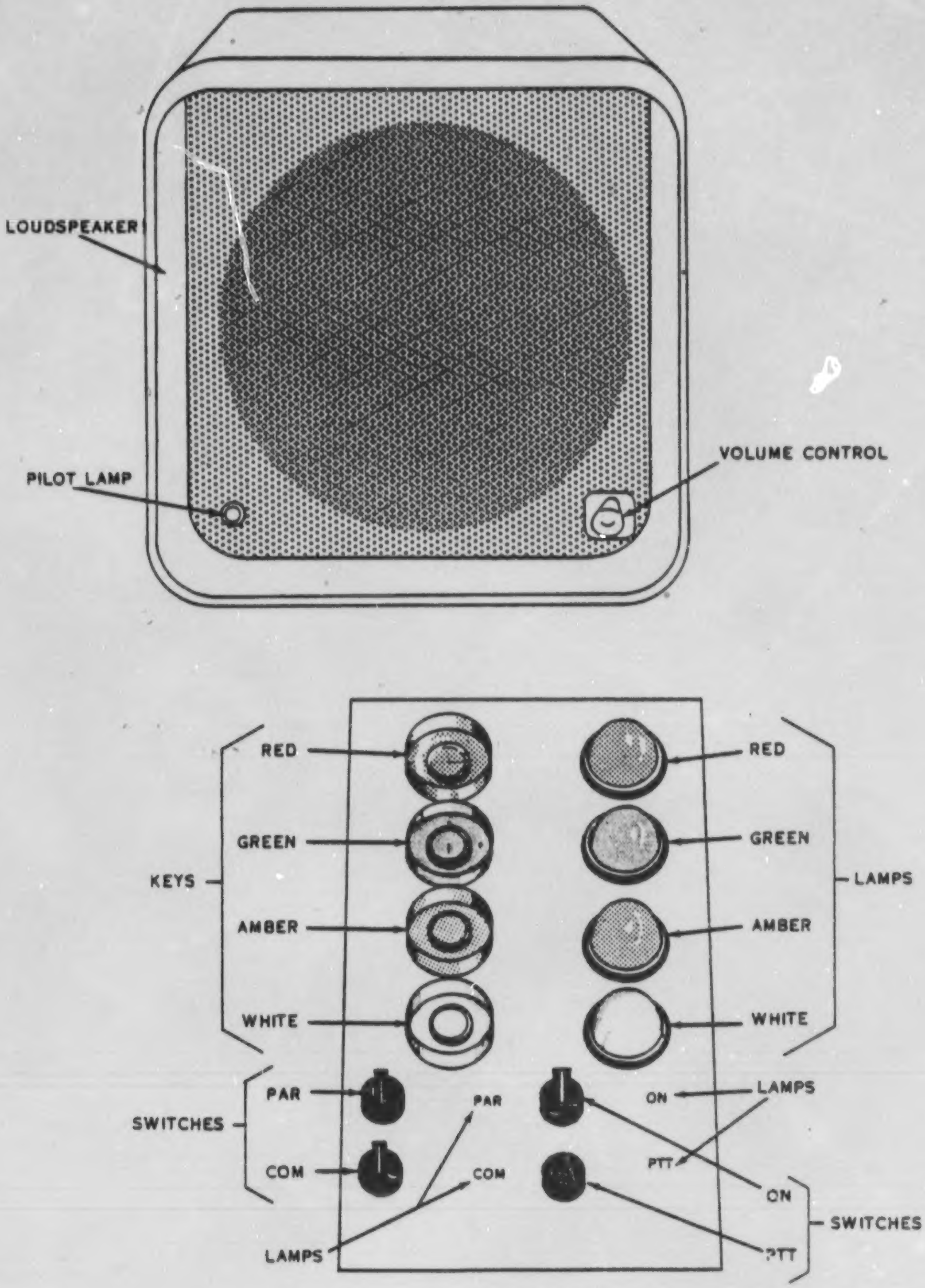
LOUDSPEAKER
PILOT LAMP
VOLUME CONTROL
KEYS
RED
GREEN
AMBER
WHITE
RED
GREEN
AMBER
WHITE
LAMPS
SWITCHES
PAR
COM
PAR
COM
LAMPS
ON
LAMPS
PTT
ON
PTT
SWITCHES

Figure 70. Typical operator's position in control tower.

lamp. The RED lamp is extinguished only by the tower operator; he presses the RED key for a second time to put out the lamp. Furthermore, while the RED key and lamp circuit are operated, the GREEN lamp is prevented from operating.

19-10. The WHITE, AMBER, and GREEN lamps can be extinguished also by depressing the associated key for the second time. However, the controller at the van must reoperate these keys to restore the lamps to normal.

9-11. Let us now consider the function of the other devices identified in figure 69. We have described visual signaling. Now we will talk about the audible communications. Although we included the loudspeakers and a chime as the audible communications devices, a hotline communications circuit includes many devices. For example, there must be switches for controlling the circuits. Two 2-position turn switches (PAR and COM) and the PTT nonlocking plunger key enable or disable these wire circuits. The voice circuits between the operations van and the control tower are one-way. The precision approach radar (PAR) voice circuit is one-way from the tower to the van. To precondition this circuit for talking, the tower operator turns the locking type PAR switch. A lamp under the letters PAR illuminates the surrounding area of the panel because of the opaque material of which the panel is made. Thus, the circuit is identified as being ready for operation. This circuit is completed through transmitting equipment in the tower and headsets at the operations van positions. Each hand transmitter at the control tower is normally connected with the radio transmitting equipment. Operating the PAR switch, in conjunction with the PUSH-TO-TALK (PTT) switch, at the tower permits voice reception with any controller using the PAR switch at his position. Remember: We said previously that the controller's transfer key allowed voice reception when placed in OFF or RADIO. The WIRE position also allows voice reception when the tower operator has pressed the PTT switch and when the tower operator and controller have both operated their PAR switches. The assistant controller receives the voice communications when his transfer key is in the same (WIRE or RADIO) position as the controller's or if his transfer key is in the RADIO or OFF position when the controller's transfer key is selected for OFF.

19-12. The one-way tower-to-van communications (COM) voice line is similar to the precision approach radar circuit. You first operate the COM switch to precondition the circuit and then the PTT switch to originate the call, and the controller or controllers operate the COM switch in the van to receive the communications. The assistant controllers would operate the transfer key in the same manner described in the last paragraph if they desire to receive the message. The operated COM switch likewise illuminates the letters COM of the controller equipment panel (see fig. 69).

19-13. The voice frequencies originating at the van are transmitted to the tower when the controller depresses the PTT key. In addition, he must place the transfer key in either the WIRE or RADIO position. The operated PTT key also results in lighting the lamp under the front panel and the letters PTT. At the tower, following the depression of the PTT key, the one-stroke chime is operated to alert the operator of the incoming call. NOTE: This tower chime also operated following the depression of the colored keys on the controller's shelf. A controller's position also has an audible device for alerting the controller, to warn him of an incoming call. The BUZZ turn switch, shown in figure 67, permits use of this buzzer or the silencing of it.

19-14. The ON switch (see fig. 69) must be turned to the ON position before any lamp (except the RED lamp) can operate. When operated, it also illuminates the area of the panel under the ON.

19-15. We noted that figure 69 showed one set of request and acknowledgment controls. Also, you learned that the operations van has three sets of these controls. The control tower also has two sets.

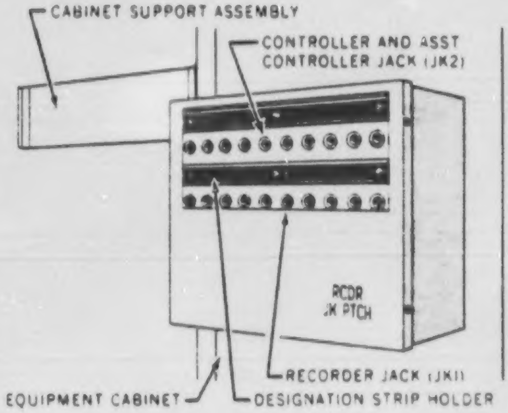

Figure 71. Patching panel for recording equipment.

In addition, the control tower has a loudspeaker common to each position. Figure 70 illustrates a typical control tower position. The speaker includes a volume control for determining the intensity of the voice output and a pilot lamp, which indicates when power is being provided to the speaker.

19-16. Return to figure 67 and note the dark environment lamp brightness control. This variable resistor provides adjustment in the circuit resistance of the lamps. If you desire more light in the darkened van, turn this control until you get the lamp brilliance that you desire. However, this resistor is used in conjunction with the LP CONT OFF-ON switch.

19-17. The six positions of the operations van are usually assigned so that some of the controllers and assistant controllers receive the COM one-way calls and the remaining personnel receive the PAR one-way calls.

19-18. The PAR and COM switch originated one-way communications can be recorded. The PTT switch originated circuit (talk circuit of van) is not connected to the recorder. The recorder jack patch assembly shown in figure 71 provides this activity. To complete the connections between the individual doing the speaking and the recorder, you use patch cords. A patch cord connects between the recording instrument jack (JKI) and the controller's jack (attendant's circuit for the position).

20. Principles of Operation

20-1. At a sporting event, you have seen people selling programs. The vendors often use expressions that mean essentially this: "You can't follow the action without knowing the people and the positions." We think that you will likewise need to know the components of this equipment and their position or location in order for you to follow the action (operation) of the circuits. Thus, we first describe equipment location. Then, we disclose some of the circuit operations.

20-2. **Equipment Location.** You know that the relay equipment for a 1A1 key system is installed in an apparatus cabinet. Furthermore, this cabinet is normally installed so that there is limited distance between the key units and the associate telephones. The 302 Switching Unit also has an apparatus cabinet and a separation between the cabinet and the telephones.

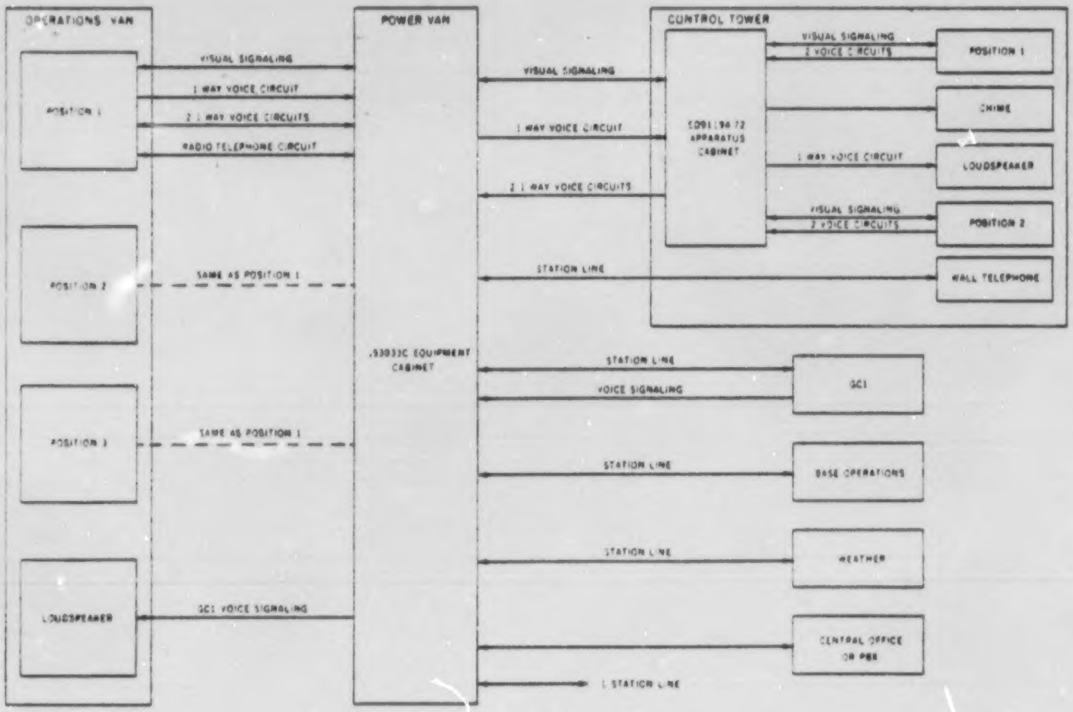
OPERATIONS VAN
POSITION 1
POSITION 2
POSITION 3
LOUDSPEAKER
VISUAL SIGNALING
1 WAY VOICE CIRCUIT
2 1 WAY VOICE CIRCUITS
RADIO TELEPHONE CIRCUIT
SAME AS POSITION 1
SAME AS POSITION 1
GCI VOICE SIGNALING
POWER VAN
53033C EQUIPMENT CABINET
VISUAL SIGNALING
1 WAY VOICE CIRCUIT
2 1 WAY VOICE CIRCUITS
STATION LINE
CONTROL TOWER
SD91194 72 APPARATUS CABINET
VISUAL SIGNALING
2 VOICE CIRCUITS
POSITION 1
CHIME
1 WAY VOICE CIRCUIT
LOUDSPEAKER
VISUAL SIGNALING
2 VOICE CIRCUITS
POSITION 2
WALL TELEPHONE
STATION LINE
VOICE SIGNALING
GCI
STATION LINE
BASE OPERATIONS
STATION LINE
WEATHER
CENTRAL OFFICE OR PBX
1 STATION LINE

Figure 72. Block diagram of 302 Switching Unit.

There is additional separation between the operator's controls and the apparatus cabinet since these controls and the apparatus cabinet are not a part of the telephone. Figure 72 indicates that the apparatus cabinet is in the control tower. Secondly, this illustration shows that there is a power van in addition to the operations van. The station telephones are connected with cable to the power van equipment cabinet, not to the apparatus cabinet. The maximum distance permitted between the two vans and the apparatus cabinet is 10 miles. The cable between the two vans is normally 40 feet long.

20-3. The apparatus cabinet (also listed as telephone relay rack) is not large enough to contain all the circuit equipment for the three positions of the operations vans and the two positions in the control tower. Hence, in the power van you will find equipment serving the positions of the operations van. Figure 73 reveals the placement of components for three positions. The numbers J53009CW-2 and J53009CY-1 identify the specific equipment units. To illustrate, J53009CW-2 is a unit that includes relays C1, CT, TR, WT1, TB1, and TB2, as well as other devices. J53009CY-1 includes relays WT2, TB3, TB4

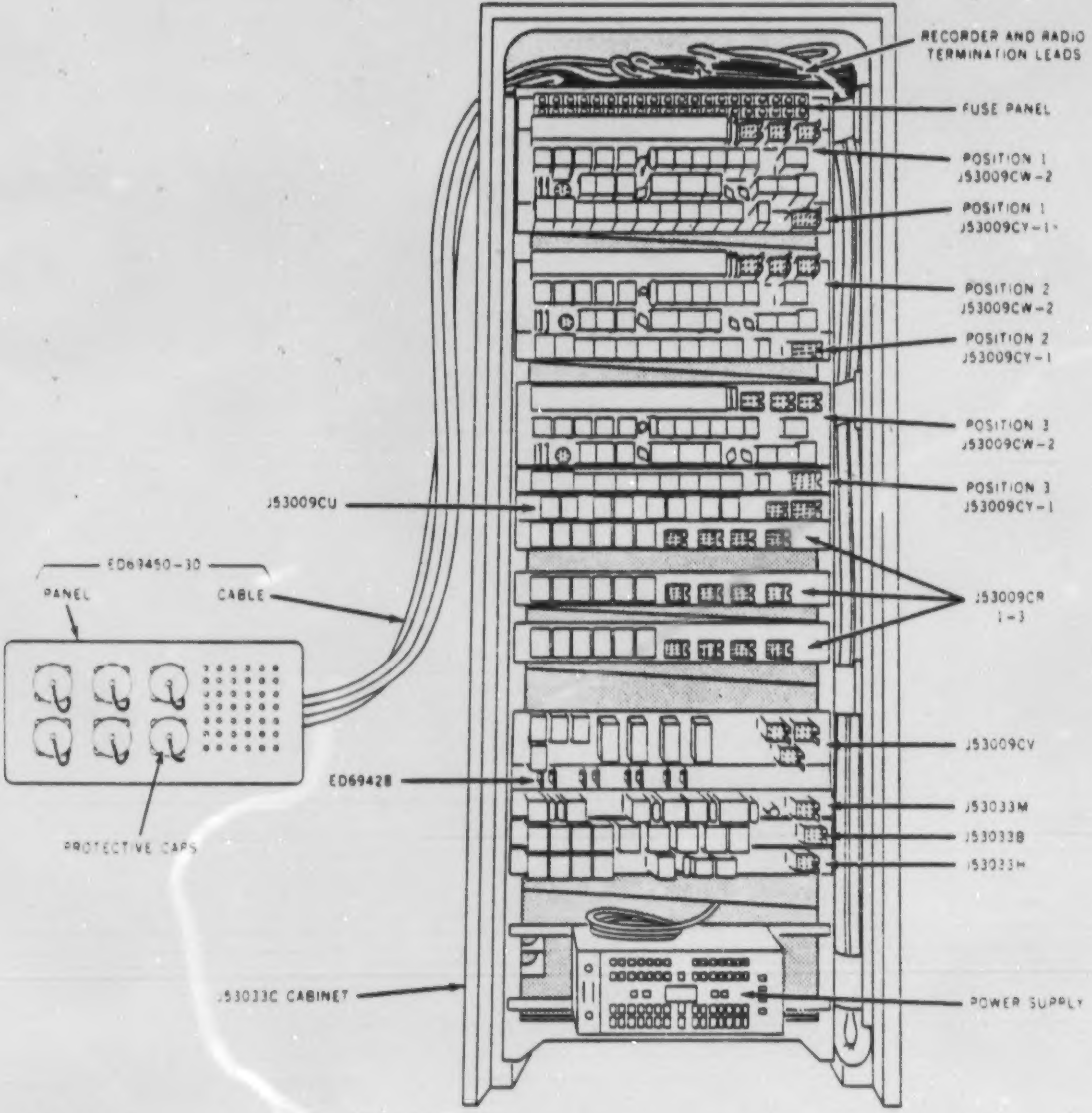
RECORDER AND RADIO TERMINATION LEADS
FUSE PANEL
POSITION 1 J53009CW-2
POSITION 1 J53009CY-1
POSITION 2 J53009CW-2
POSITION 2 J53009CY-1
POSITION 3 J53009CW-2
POSITION 3 J53009CY-1
J53009CU
ED69450-30
PANEL
CABLE
J53009CR 1-3
J53009CV
ED69428
J53033M
J53033B
J53033H
PROTECTIVE CAPS
J53033C CABINET
POWER SUPPLY

Figure 73. Power van equipment cabinet, front view.

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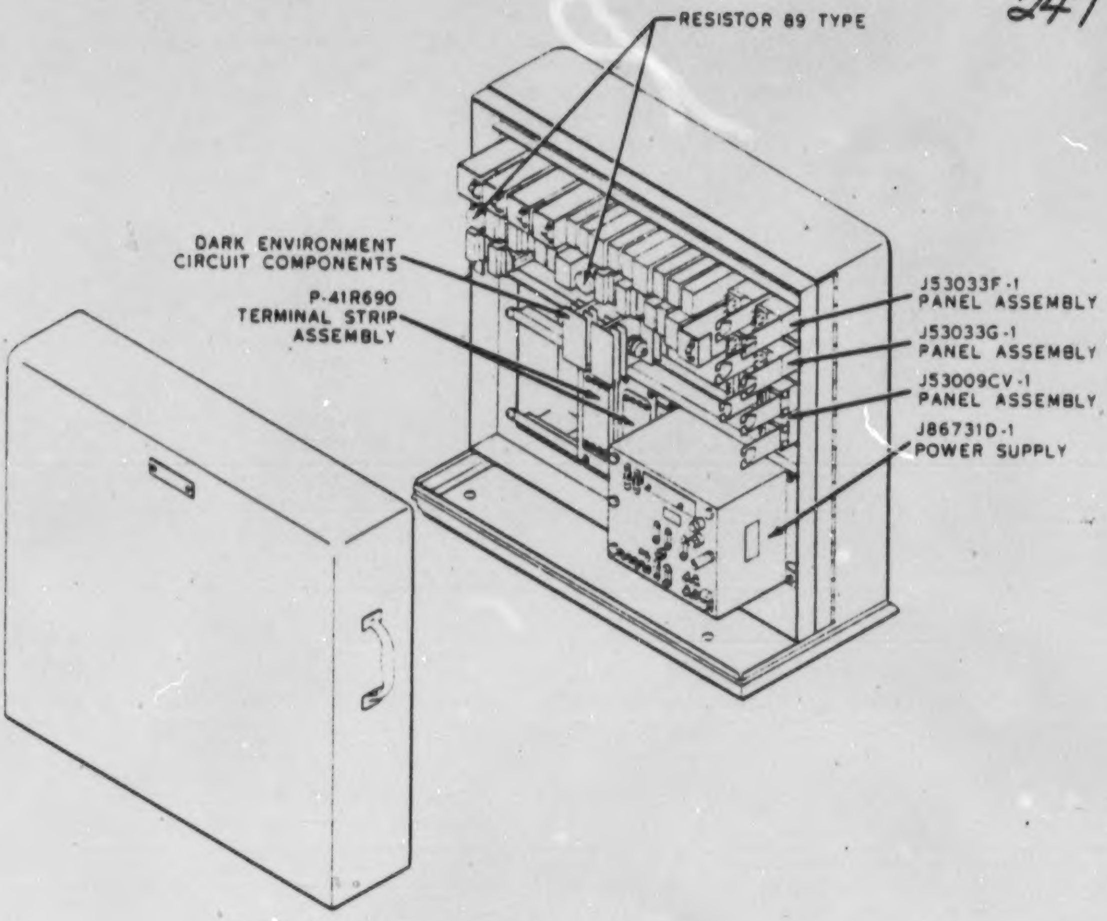


RESISTOR 89 TYPE
DARK ENVIRONMENT CIRCUIT COMPONENTS
P-41R690 TERMINAL STRIP ASSEMBLY
J53033F-1 PANEL ASSEMBLY
J53033G-1 PANEL ASSEMBLY
J53009CV-1 PANEL ASSEMBLY
J86731D-1 POWER SUPPLY

Figure 74. Control tower apparatus cabinet.

and other devices. Duplicate units for other positions are included on the rear of this gate. Additional units are installed there, too. For instance, the J53033S (PBX or central office signaling) unit and a ringing source are placed there. Figure 74 illustrates a telephone relay rack of a control tower. Again, the equipment units are identified in the manner already described. For example, equipment J53033F includes relays AC(1), AC(2), AC(3), and AC(4), and associated devices.

20-4. Figure 72 provides a review of information discussed in Section 19. To illustrate, there are two communications circuits for the GCI station, and visual signaling is only possible at the operations van and the control tower. Likewise, the arrowhead arrangement on the visual signaling lines extending between the operations van, the power van, and the control tower show that the circuits permit two-way operation: Either the tower operator or the controller can originate the signal and light the lamps of the distance station. Furthermore, figure 72 shows a one-way voice circuit between the operations van and the control tower, and two one-way voice circuits that begin at the control tower and terminate at the operations van. You must remember that the van personnel press the PTT switch to originate the call to the tower and that the tower operator first operates the PAR or COM switch to prepare his one-way voice circuit, after which he depresses the PTT pushbutton, which permits his voice to be received by the van personnel.

20-5. **Circuit Operation.** We know that there are many features required during a call progression. Consequently, several circuits are necessary to meet the requirements. In addition, various types of calls are provided. For example, telephone calls are made where the central office provides the ringing, and station calls are made that require ringing current from the switching unit power source. Therefore, circuits are provided that produce these variations. We will illustrate and describe a limited number of the circuit operations. This effort should prepare you for your assignment to a work center that has a 302 Switching Unit installed.

20-6. *Station line selection.* You learned that a depressed PICKUP key for a 1A1 key system operated the A relay in a KTU. The same result is provided with the 302 Switching Unit. However, the controller must do more than press the LINE PICKUP key. Look at foldout 5 as you think about this latter statement. It shows the LINE key at the lower left and the A relay at the upper left. Let us find out how they interconnect. Note the controller's headset, the controller's wire-line transfer key, and the SL relay. Each of these devices affects the A relay circuit. Contact EMB12 of relay SL must operate to complete the operating circuit for relay A. Accordingly, the SL relay must operate before relay A can operate. Yet, to operate relay SL you must connect a ground potential to the terminal identified as K to the left of the relay. The operated LINE key partially does this. The additional unit that connects the ground potential to relay SL is the operated relay WT1. To operate relay WT1, you must place the transfer key in WIRE. (Either selection OFF or RADIO results in opening the circuit for relay WT1.) In addition, the operating circuit of relay WT1 is completed by the installed controller's headset. Thus, we now realize that you must insert the plugs of the headset into the jacks, operate the transfer key to WIRE, and press the LINE PICKUP key when selecting a telephone line. Remember: The PICKUP and transfer keys, as well as the headset, are in the operations van. But, the SL, WT1, and A relays are in the equipment cabinet at the power van.

20-7. The operated SL relay provides a holding circuit by operating contact EMB8, completes the operating circuit for the supervisory lamp with contact EMB5, and partially completes the H relay's operating circuit with contact EMB7. At the same time, the operated contacts EMB1 and EMB4 of relay SL connect tip and ring of the telephone station to the line termination equipment of the 302 Switching Unit.

20-8. The operated relay A of the station line signaling circuit connects contact 3 with contact 4B to light the LINE or BUSY lamp. Top contacts 2 and 5 open following the operation of relay A to prevent the operation of relay L. Otherwise, relay L would operate with the lifting of the telephone handset from the cradleswitch. In conjunction with the operated A relay, relays PL and C operate. Contact 2 of operated PL completes the operating circuit of relay S. The operated S relay connects 20-cycle ringing current to contacts 4 and 7.

20-9. We have said that you selected a station telephone line which requires ringing current from the power van. You must then press the FLASH AND RING key. As a result of this key operation, relay FR operates. The operated contacts EMB6 and EMB8 of relay FR extend the 20-cycle ringing current from contacts 4 and 7 of relay S to the line for the telephone station.

20-10. The lifted handset at the called telephone provides a complete circuit for conversation between the two people. Foldout 5 shows that contacts EMB1 and EMB4 of relay SL and EMB6 and EMB8 of relay FR are included in this communication circuit between the telephone station and the controller's headset.

20-11. *Holding a station line.* You are aware also that all lines in the 302 Switching Unit can be held while you perform another function. Again, this holding condition is accomplished by pressing a HOLD pushbutton. It is evident in foldout 5 that two H relays operate following operation of the HOLD key. Contact EMB7 of the operated SL relay completes the operating circuit for relay H in the station line signaling circuit. As a result of the H relay operations, relays A, PL, and C return to normal. The released A relay releases contacts 2T and 5T thereby operating relay L. This operation is the result of the telephone station attendant having lifted his handset. Contact 2 of operated relay L completes the holding circuit for both H relays. We know that this holding circuit is required because the HOLD pushbutton does not lock operated following depression.

20-12. Several methods for releasing the line are possible. You can operate a second LINE key, the RLS key, the transfer key to RADIO or OFF, or remove the controller's headset from J53033P-1.

20-13. Analysis of the RLS key connections, shown in foldout 5, reveals that this operated key connects ground to relay CR1. As a result, relay CR1 operates. Operated contact BM12 of relay CR1 completes the operating circuit of relay CR2 and opens the holding circuit for relay SL. The operated CR2 relay opens the operating

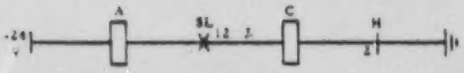


Figure 75. Operating circuit for relay A when connected with central office line.

circuit of relay CR1. The released SL relay opens the operating circuits of relays A, PL, C, H, and the HOLD or SUPV lamp. Release of the RLS key returns relay CR2 to normal. Now the equipment is prepared for another selection.

20-14. *Central office or PBX line selection.* When considering the selection of a telephone that is connected with a central office, we find that the circuit is slightly different from the station line circuit. The instructions near the top center and above the PL and C relays on foldout 5 indicate that the A relay of the central office line signaling circuit connects to the J lead. Using this information, try to visualize a relay A and the contact EMB12 of relay SL connected to the J lead. You should realize that the operated SL relay for this selected circuit completes the relay A operating circuit. However, in this case, only the relay C operates in conjunction with the A relay. Look now at foldout 7. You will see relay C at the left center of this illustration. Remember: Negative battery is connected to relay A to complete the operating circuit for relay C. Figure 75 is a line drawing of this completed circuit. Contacts 3 and A of operated relay C (FO 7) connect relay CB to ring side of the line. Note that contacts 1 and 3 of relay S and contacts 5T and 6 of relay CT connect relay CB to tip of the line. You learned that resistors in parallel result in less resistance than either resistor has separately. Relay CB has two windings in parallel. This reduced resistance across the central office line causes a relay to operate in the central office; thus, it starts the call progressing through the central office equipment. Return now to our foldout 7 and the 302 Switching Unit equipment. At the same time that the central office equipment progresses the call forward, it returns power to the CB relay, thus operating it. Before we consider the effects of the operated CB relay, let us determine further effects of operated relay C.

20-15. Contacts 1 and 2T of the operated C relay complete the operating circuit of relay C1. Contacts 3 and 4B of operated relay C1 light the DIAL lamp and shunt the "A" suppression circuit. They also connect ground potential to relays TB1 and TB2 (see FO 7). Contacts 3 and 4T of this same relay connect 24 volts negative battery to relay RS. Relay RS now operates. Contacts 1 and 2B of operated relay RS complete a duplicate circuit to the 3 and A contacts of relay C and therefore insure a connection between relay CB and ring side of the line. Operated contacts 3 and 4B of relay RS complete a connection for the operating circuit of relay CT. Contacts 4 and 5T of operated relay RS short-circuit the receiver of the controller's headset. Figure 76 illustrates this circuit to the receiver. Of course, you must recall the activities described in paragraph 20-6 in order that this circuit can be completed. We learned in that earlier description that relay WT1 was operated. Foldout 7 illustrates that the make contacts 3 and 4T of operated relay WT1 complete the operating circuit of relay WT. Contacts 1 and 2B, plus 4 and 5T, of operated relay WT, make required connections for this receiver short circuit. Operated contacts 4 and 5B, plus 7 and 8B of this same relay, connect the transmitter of the controller's headset to the primary winding of the "A" induction coil.

20-16. We learned that relay CB has operated. Contacts 1 and A of operated relay CB are included in the operating circuit for relay CT. Contacts 1 and 2T of operated relay CT provide the relay a holding circuit while, at the same time, contact 1 breaks from contact 3 to open the operating circuit of relay RS. Contacts 7 and 8T of operated relay CT connect the secondary of the "A" induction coil to the ring side of the central office line. Operated contacts 1 and 2B of relay CT connect the receiver of the controller's headset to the secondary of the

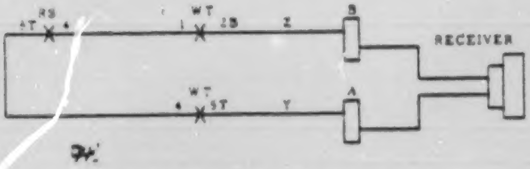


Figure 76. Short circuit of controller's headset receiver.

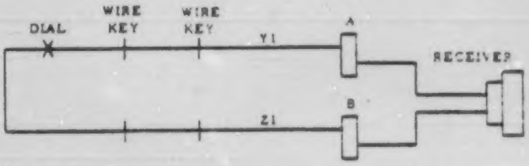


Figure 77. Dialing shunt for controller's receiver.

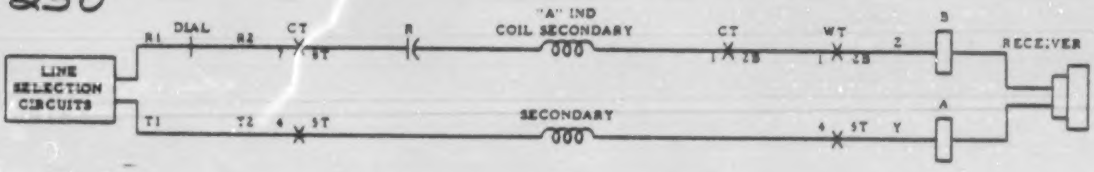


Figure 78. Transmission circuit for 302 Switching Unit.

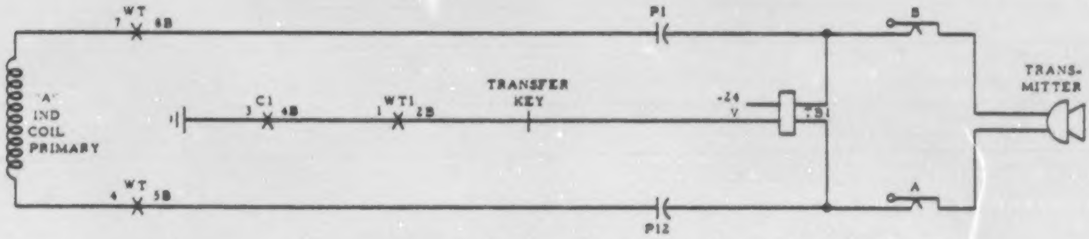


Figure 79. DC circuit for operating the controller's transmitter.

"A" induction coil. The duplicate circuit connection between relay CB and ring of the line, which was formed by contacts 1 and 2B or relay RS, is now replaced by operated contacts 5 and 6B or relay CT. Contacts 4 and 5T of operated relay CT connect tip of the central office line to the secondary of the "A" induction coil. Furthermore, contact 5T is separated from contact 6 by the operated CT relay to open the low-impedance noninductive winding of relay CB. Since the central office equipment is operating, this increased resistance of the CB relay circuit will not have any major effect on the call's progression.

20-17. Having the central office connected with the 302 Switching Unit following your selection of the line, you should hear a dial tone in the controller's headset receiver. Now you can dial the number.

20-18. We know that the major results from the operated dial are in the central office equipment. Yet, some changes are made to the 302 Switching Unit circuits. Again, look at foldout 7. At the left of the page you can see the symbol for the dial. The operated dial makes two contacts. One contact directly connects ring of the central office line to tip of the same line. As a result, relay CB is momentarily released in this 302 Switching Unit. The second contact short-circuits the controller's receiver for the second time. Figure 77 illustrates this new shunt circuit for the receiver. The restored dial reoperates the CB relay and removes the shunt of the controller's receiver.

20-19. The lifted handset at the called telephone provides a complete circuit for conversation between the two people. Figure 78 shows the circuit between the tip and ring of the line selection circuits and the receiver of the controller's headset. You learned, too, that dc is required for a telephone transmitter when a person speaks into it. Figure 79 illustrates the connections for relay TB1, which is the relay that provides dc to the transmitter. In addition, it shows the connections between the controller's headset transmitter and the induction coil primary. Relay TB2 provides dc to plugs C and D, which serve as reserve connections for the controller's headset. Plugs A and B are normally used because their circuit has provision for an emergency battery.

20-20. Foldout 7 shows the emergency talking battery supply to the right center of

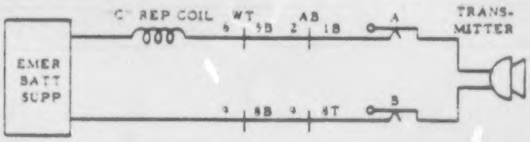


Figure 80. Emergency battery circuit.

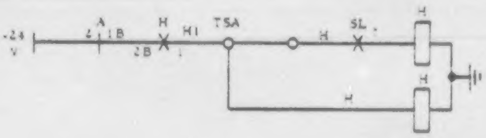


Figure 81. Holding circuit for H relay.

the illustration. It becomes effective when there is power failure; thus all relays are released. Relay AB is one of these relays. It is normally operated; hence it keeps contacts 1B and 2 plus 8T and 9 from shunting capacitors P1 and P12. Following release of relay AB and the shunt of these two capacitors, the dc circuit for the emergency 3 volts of power is complete through the controller's headset transmitter. Figure 80 illustrates this circuit.

20-21. *Holding a central office or PBX line.* We noted circuit differences when making a station line selection and when making a central office or PBX line selection. For example, the PL relay operated when selecting a station line but did not operate when selecting a PBX or CO line. Accordingly, there will be differences in the effects that result from operating the HOLD key. For one thing, when the selected line is served by a central office or PBX, relay PL cannot be released following the operation of both H relays. Secondly, there is no L relay in a PBX or CO signaling circuit. A pair of contacts on the A relay are used to complete the H relay holding circuits following release of relay A. Figure 81 is a line drawing of such a holding circuit. Remember: Several lines can be held at the same time and any held line can be reselected by operating the associated LINE key.

20-22. *Central office or PBX line release.* The equipment release for the CO or PBX line is done in the same manner as described in the last paragraph. As a result of your depressing the RLS key, relays CR1 and CR2 operate in the way previously described. Also, relays SL, A, C, and H release. Returning to foldout 7, we can analyze the after effects of the release of relay C. The released C relay opens the operating circuit of relay C1 and one parallel connection to relay CB. The released C1 relay releases the TB1 and CT relays, and extinguishes the DIAL lamp. The released CT relay returns relay CB to normal by opening contacts 5 and 6B (the second parallel connection for operating relay CB). Operation of the transfer key to RADIO or OFF returns the equipment to normal because either position selection opens the operating circuit

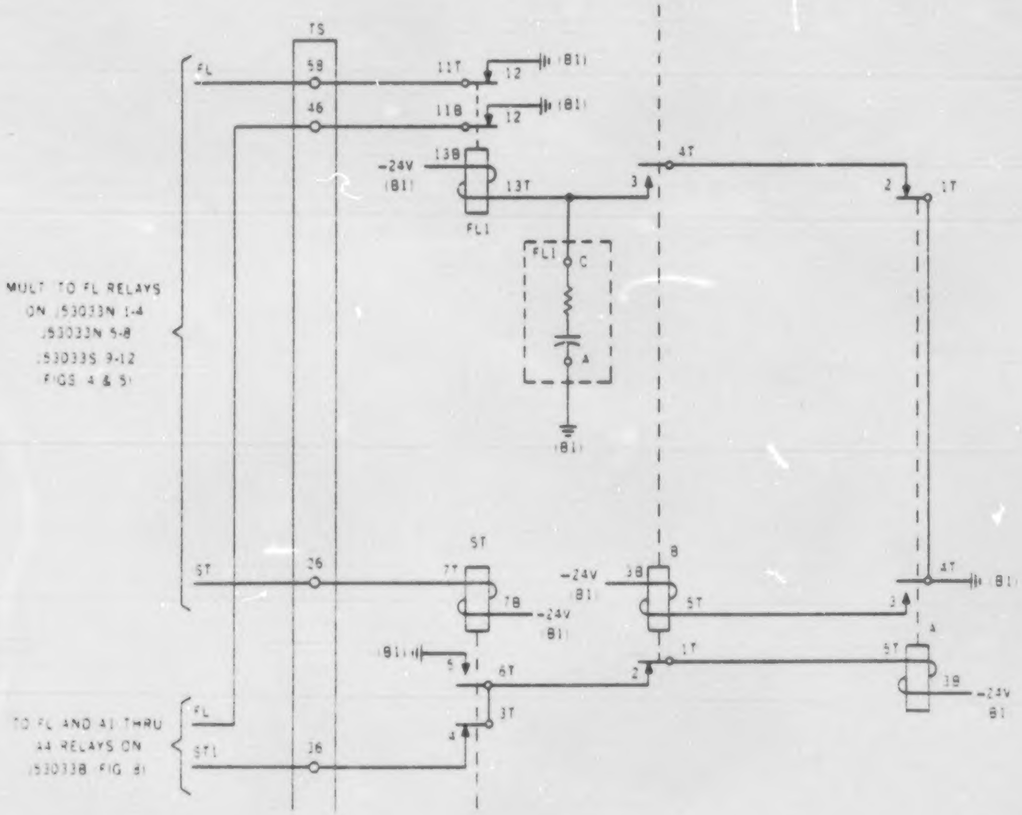


Figure 82. Flashing lamp and audible signal control circuit.

of relay WT1. Removal of the headset also returns the equipment to normal. The restored WT1 relay releases relays WT and SL. The released SL relay opens the operating circuit of relays A and C. The results that follow the release of these relays have already been described.

20-23. *Incoming signal, flashing lamp, and answering.* The actions that result when a person selects our 302 Switching Unit for a call are comparable to what you learned with the 1A1 and 1A2 key systems. To illustrate, the incoming call causes a lamp to flash and then, following your operation of the controls to answer the call, the lamps change to steady and the transmission circuit is complete. Of course, you perform more operations with the 302 Switching Unit, and the nomenclature of the devices may deviate from the former systems. We are not going into the operational procedures that produce the circuit effects because you should be able to determine them now. In an effort to help you recognize the circuit devices and their effects, we will list most of them.

20-24. The lifted handset at the telephone station operates relay L in the station line signaling circuit. The operated L relay, in turn, starts a relay operational sequence which flashes the lamp. This sequence is similar to the method used in the 1A1 key system where the FA, FB, WS, WT, and W relays provided winking lamps. In this system, relays FL, ST, A, B, and FLI provide the interruptions in the lamp circuit. However, the interruptions are of longer duration than was the wink so that the lamp provides a flashing effect. Figure 82 includes these flashing circuit relays. NOTE: We are not showing the foldout that has relays L and FL and the connections between relay L and relay FL of the J53033N unit or the FL connections between the J53033N unit and the J53033M unit (fig. 82) because we must limit the number of complex circuits and diagrams that we use in the manuscript. We ask you to take for granted that the ground at contact 12 of relay FL1 (fig. 82) completes the operating circuit for a relay FL. Furthermore, remember that contacts of the operated L and FL relays complete the operating circuit for the LINE lamp. The operated FL relay, in turn, connects ground to relay ST (also shown in fig. 82).

20-25. Operated contacts 5 and 6T of relay ST complete the operating circuit for relay A (see fig. 82). Then the operated relay A completes the operating circuit of relay B. The operated B relay opens the operating circuit of relay A. Now the operating circuit relay FL1 is complete. Included in this operating circuit are contacts 3 and 4T of relay B and 2 and 1T of relay A. The operated relay FL1 disconnects ground from leads FL. Consequently, relay FL is released. The released FL relay opens the LINE lamp circuit. Your analysis of figure 82 should also disclose that the released relay A opens the operating circuit of relay B. The released B relay returns relay FL1 to normal while completing the operating circuit of relay A again. Here again, the circuit is prepared for the relay operational sequence which provides an interruption in the lamp signaling circuit.

20-26. Since you would normally have the headset inserted in the associated A and B jacks, you then respond to the flashing lamp by making sure that the transfer key is in WIRE and operating the LINE key. As a result, relay SL operates to complete the operating circuit of relay A (FO 5), complete the circuit for the SUPV lamp, and connect the originating station with the transmitting circuit of the controllers. The operated relay A makes the contacts that light the LINE lamp at the three operations van positions steadily. The same contacts that provide the steady power to the lamps open the flashing lamp circuit. You should also recall that the operated A relay opens a set of contacts that prohibit the L relay from operating.

20-27. The incoming voice signal from the GCI station is different in that the 106B loudspeaker for the operations van is used. The voice signal line from this station is connected to contacts of the A relay. The incoming voice is heard by the people of the operations van; then one of them operates the LINE key. Consequently, the A relay is operated. This operated relay opens the loudspeaker circuit while connecting the talking circuit of the controller with the GCI station telephone line.

20-28. *White lamp signal at requesting location.* We learned when describing the request and acknowledgment signaling circuits that you turn the ON switch and depress the WHITE pushbutton when making a request. Foldout 6 will permit us to analyze the effects of these two control operations.

20-29. Before we consider the circuits, however, let us note some of the features of this schematic. At the left side of the illustration you can see a block labeled OPERATIONS VAN. Within this block is a smaller block. The latter block represents the J53033A key and lamp unit, which is installed in the operations van. The key and

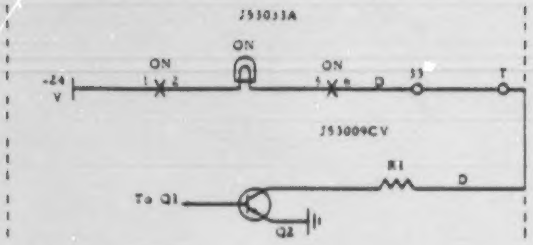


Figure 83. ON lamp operating circuit.

lamp unit is shown to have eight lamps and eight keys. Positioned near the key symbol are contacts that complete or break circuits following operation of the key. For example, by pressing the RED key you connect ground at contact 6 to the A4 lead. The A4 lead is also connected to connector pin 26 of the cable for the operations van. This cable is multipled with position 2 so that the lamps at each position will operate when the key is operated at any position. Lead A4 is further connected to lead A4 in the power van. In this power van the A4 lead is also multipled to position 3. This cable that extends between the two vans is shown terminated with the J53033C equipment cabinet in the power van. Included as units of the equipment cabinet are the J53033H, J53033B, and J53033F equipment. The A4 lead is connected with terminal 36 of the terminal strip for J53033B. Tracing this A4 lead further results in observing its connection with CR1 and relay A4.

20-30. Now, let us consider the operation of the ON key. First, the operated ON key results in lighting the ON lamp. The 24-volt battery potential for this lamp is connected to contact 1 of the ON switch. The ground potential for this lamp is found in the dark

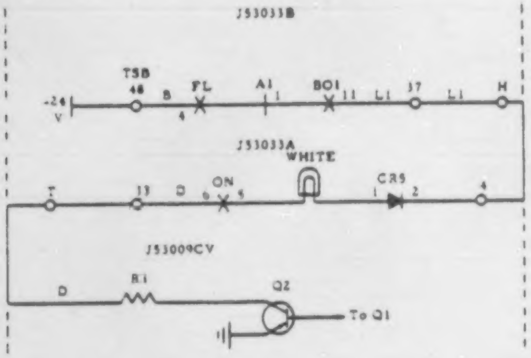


Figure 84. WHITE lamp operating circuit.

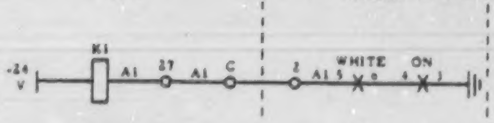


Figure 85. Operating circuit for relay K1.

environment lamp control circuit. Foldout 4 is a schematic diagram of this latter control circuit. Figure 83 illustrates the operating circuit of the ON lamp. Remember: The operations van personnel normally work with the overhead lights either dim or off so that they can read the radarscopes more efficiently. So, the LP CONT switch is regularly positioned at ON. This switch is at the upper right in foldout 4. When this switch is ON, the CO relay is released. In addition, the R4 variable resistor permits you to adjust the intensity of the lamp. You make this change in the lamp brilliance by changing the voltage at the D leads. These leads are shown at the lower left in foldout 4. You should realize from your tracing of foldout 4 that there is a completed dc circuit at all times for the Q2 transistor. The negative voltage for this circuit is at contact BM8 of relay CO. From this contact you trace the terminal 21 of terminal strip B, through resistor R6, resistor R4, resistor R1, and then to ground through the Q2 transistor. Of course, transistor Q1 and resistors R2 and R3 form a parallel branch to R6, R4, and R1. Together the two branches permit you to determine the current in the position lamps. For example, the movement of the slider on R4 changes the voltage at the base of transistor Q1. As a result the current in Q1 is changed. All current changes in Q1 are likewise observed in transistor Q2. Since Q2 is in series with R1, R4, and R6 and they form the D lead regulator circuit, this current change causes a different voltage to be reflected at the D leads. Ground potential is at the D leads when the LP CONT switch is turned to OFF.

20-31. Depression of the WHITE pushbutton likewise lights the WHITE lamps for the three positions in the operations van.

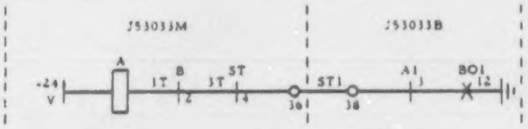


Figure 86. Operating circuit for relay A in J53033M unit.

Figure 84 illustrates the operating circuit for one position lamp. Since contacts 5 and 6 of the ON switch are included in this lamp circuit, it is evident that the circuit would not be complete without your having operated the ON switch first. Also, since transistor Q2 is included in this lamp circuit, it is obvious that the adjustment of variable resistor R4 controls the brightness of this lamp. NOTE: The D lead of foldout 6 is not shown with multiplying connections to the associated positions. Hence, one dark environment lamp control circuit is used for each position.

20-32. You should remember that the WHITE lamp must flash when you press the button for request. The operational sequence that flashes the lamp includes the FL relay, which is operated when the power is turned on for the equipment. This FL relay is near the middle of the page in foldout 6. Operated contacts 5 and 6 of the WHITE switch start this flashing because they connect ground to relay K1 in the J53033B unit. Figure 85 shows the operating circuit of relay K1. Contact M1 of operated relay K1 completes the operating circuit of relay BO1. Relay BO1 remains operated following your release of the WHITE pushbutton because of its holding circuit through contact EMB8. This operated contact 8 also completes the operating circuit for relay BR1. The operated BO1 relay connects ground at contact EBM12 to the ST1 lead, which in turn is connected to relay A in the flashing and audible signal control unit (fig. 82). Figure 86 illustrates this operating circuit for relay A. We learned that the A relay works in conjunction with the B relay and the FL1 relay. The operation and release of relay FL1, in turn, releases and reconnects contacts 11B and 12. These contacts then release and reoperate the FL relay (see foldout 6). While the FL relay is released, the operating circuit to the WHITE lamps is open. Then the reoperated FL relay completes the operating circuit of the lamps again. The multiple connections for the cables provide the lamp circuits to positions 2 and 3.

20-33. Flashing lamp is also required at the control tower. The connection that provides this response is shown at the center of the page and near the bottom of foldout 6. By tracing the L1 lead from this point you will find that the intermittent operation of relay FL also places 24 volts negative battery at interrupted intervals to an ac relay circuit of the control tower. Accordingly, the release and operating sequence of the FL relay releases and reoperates the associate control tower AC relay. The affected AC relay opens and makes contacts that flash the WHITE lamps at the tower positions. The tower equipment is not shown in foldout 6; therefore you cannot trace all the connections while using the illustrations of this course. We repeat, we have included a minimum of illustrations, so you must use technical order foldouts to trace all of the complete circuits.

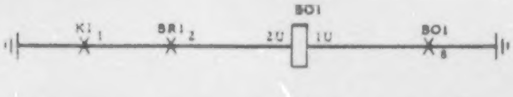


Figure 87. Shunting circuit for relay BO1.

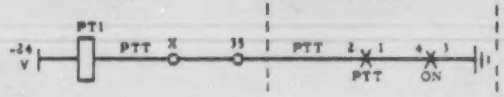


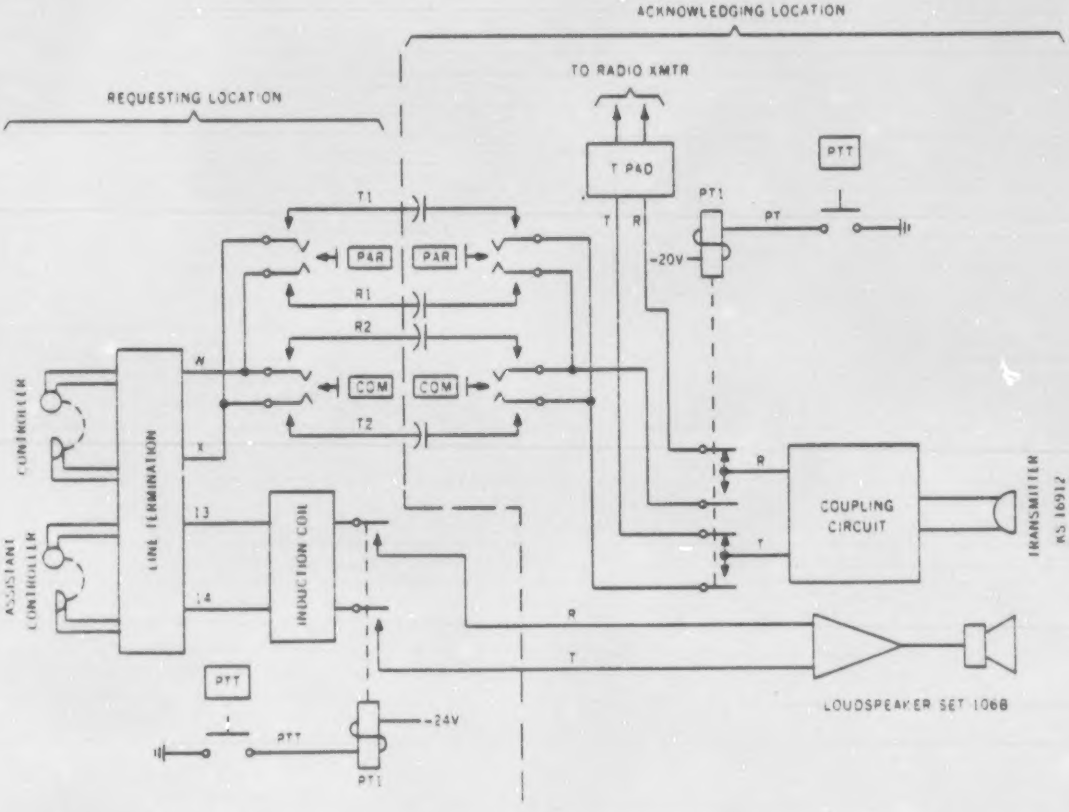
Figure 88. Operating circuit for relay PT1.

20-34. The tower operator operates his WHITE pushbutton to acknowledge the request signal. This action stops the flashing of the WHITE lamp. The operated WHITE button in the tower connects ground potential to lead B1, (see the bottom left center of foldout 6). Thus, relay AC(1) operates. Contacts 2 and 5 of operated relay AC(1) complete the operating circuit for relay A1. Operated contacts EBM3 of relay A1 complete a holding circuit while, at the same time, removing the ground potential to lead ST1. Accordingly, this removal of ground potential from the flashing signal control circuit prevents the sequence relays from flashing the lamp. Contact EBM 2 of operated relay A1 connects uninterrupted 24 volts negative battery to the tower lamps. Contact EBM1 of this relay provides the steady negative battery to the WHITE lamps at the operating van.

20-35. The flashing and steady lamp operating principles for the AMBER and GREEN lamps are the same as for the WHITE. The difference in tracing their circuits is that you use lead L2 and relays K2, BO2, BR2, and A2 for the AMBER lamp and lead L3, relays K3, BO3, BR3, and A3 for the GREEN lamp.

20-36. Relays K4, BO4, BR4, and A4 are used with the RED lamp, and they function in almost the same manner as do the preceding relays. However, we know that there must be a difference, because the RED lamp flashes only when the tower operator presses the RED pushbutton at his position. Then the lamp becomes steady following the operation of the RED button at the controller's position. This equipment functions in the desired manner because the operated AC(4) relay completes the operating circuit for relay K4. Operated contacts 5 and 2 of relay AC(4) connect ground to lead B4, thereby operating relay K4. Operated relay K4 does the same functions as previously described; for instance, it completes the operating circuit for relay BO4, connects ground to lead ST1 of the flashing signal control circuit, and connects interrupted negative battery to the RED lamps. When the controller presses the RED pushbutton, he connects ground potential to the A4 lead. This grounded lead operates the A4 relay. The operated A4 relay removes ground from the ST1 lead while connecting uninterrupted negative battery to the RED lamps of the operations van and control tower. NOTE: If the controller makes a request by pressing the RED button, the described conditions prevent the RED lamp from flashing. To illustrate, the grounded A4 lead operates the A4 relay, which in turn completes the operating circuit of relay K4 with operated contact EM9. Secondly, the ground connection, which starts the flashing signal control relays operating in sequence, is opened at contact EBM12 of relay A4. At the same time, negative 24 volts battery is connected to the RED lamps.

20-37. The operation of subsequent colored pushbuttons extinguishes the lamp that preceded it. For example, the operation of the AMBER button restores relay A1. Foldout 6 shows the connection that releases these relays. Contact B9 of released relay BO2 provides the - 24 volts for relay BO1. Yet the operation of the AMBER button completes the operating circuit of relay K2. The operated relay K2 then operates relay BO2. Now relay BO1 must restore. Research of the connections for each of the BO relays will reveal that the operated RED button shuts off the GREEN lamp. Also, the operated GREEN button shuts off the AMBER lamp. Further analysis reveals, however, that the operated BO relay for the fourth circuit (BO4) does not prevent you from signaling that another


ACKNOWLEDGING LOCATION
REQUESTING LOCATION
TO RADIO XMTR
T PAD
PTT
PT1
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PAR
R1
R2
N
COM
COM
X
T2
CONTROLLER
LINE TERMINATION
ASSISTANT CONTROLLER
13
14
INDUCTION COIL
R
T
COUPLING CIRCUIT
TRANSMITTER KS 16912
R
T
LOUDSPEAKER SET 1068
PTT
PTT
-24V
PT1

Figure 89. Schematic diagram of one-way voice circuits in 302 Switching Unit.

airplane is approaching. You can press the WHITE and AMBER pushbuttons to identify the plane positions while the RED lamp circuit is operating. NOTE: With the AMBER lamp and circuit operated, following depression of the AMBER pushbutton to extinguish the WHITE lamp, you can press the WHITE button again. As a result, the WHITE and AMBER lamps will glow simultaneously. The -24-volt battery potential at contact M1 of relay BR2 makes this feature possible.

20-38. A lamp can be extinguished by the request originator through his operation of the associated key for a second time. To illustrate, assume that the WHITE lamp is without interruption. This condition prevails because relays BO1, BR1, and A1 are operated. Now your depression of the WHITE button for the second time reoperates the K1 relay. As a result the ground potential on contact M1 at relay K1 is extended to contact EBM2 of operated relay BR1. Since this EBM2 contact is now connected with the 2U terminal at the winding of relay BO1, the relay is shunted. Figure 87 illustrates the shunt circuit. The A1 relay is restored because of the release of relay BO1. Having restored relays BO1 and A1, you release the WHITE switch. This action restores the K1 relay. The ground at contact M1 is thus removed from the operating circuit of relay BR1. The three relays (A1, BO1, and BR1) are now normal again.

20-39. *One-way voice selection.* Foldout 6 shows the voice circuit components included in the power van. We have seen that the components in this van are under the control of the controllers and assistant controllers. For this reason we will consider the operations van-to-control tower talking

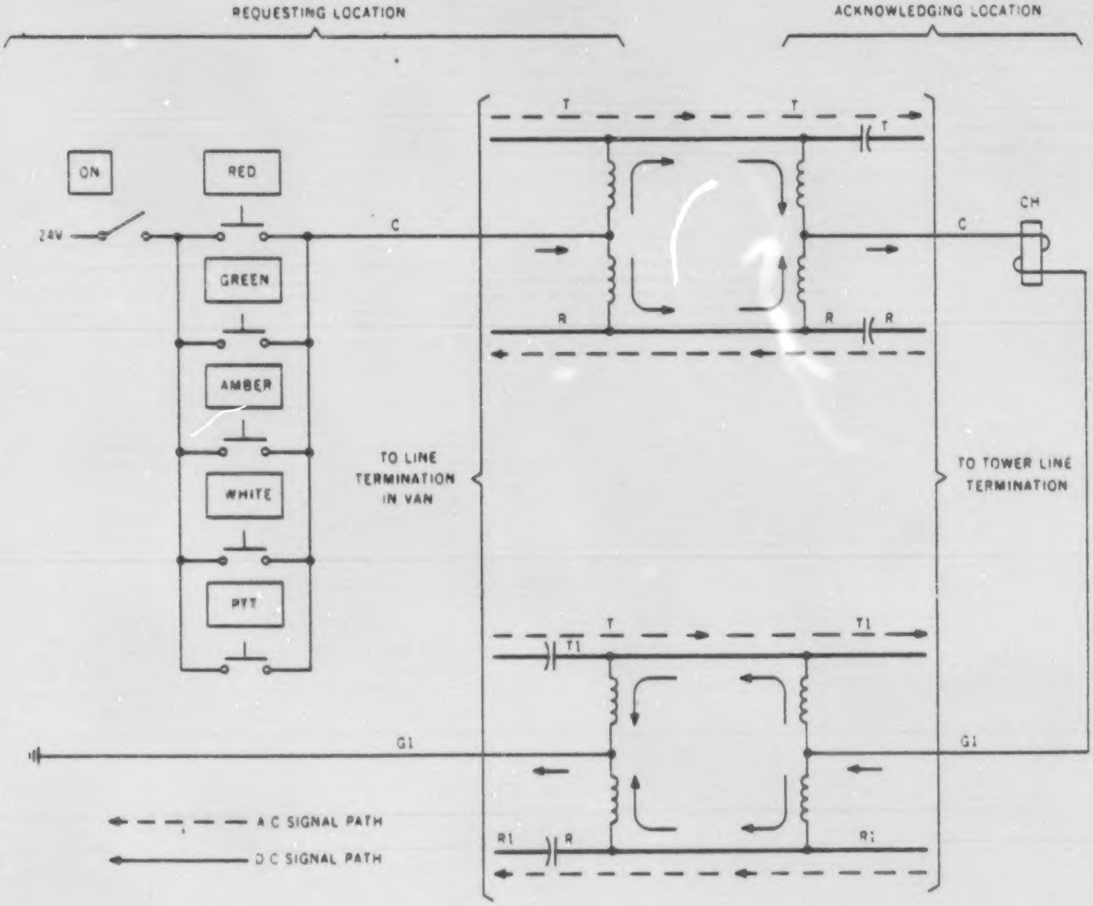

Figure 90. Simplex circuit.

circuit, which is originated by a controller. We are also assuming that you are at the first controller position when originating the radio call. Your operation of the PTT pushbutton starts the procedure. You can see that contacts 2 and 1 of the PTT button complete the operating circuit of relay PT1. Figure 88 shows this relay operating circuit. Operated contact 8 of relay PT1 completes the PTT lamp operating circuit. NOTE: There are three PT1 relays, one relay for each of the three positions. Yet, the PTT lamp at all positions operates regardless of the relay that is operating. This feature results from the connection provided by contact 8 at each PT1 relay.

20-40. Contacts 4 and 6 of operated relay PT1 complete the connections between the controller's radio and wire termination (see FO 7) and the primary of the "A" induction coil. The voice circuits are shown with heavy black lines. Accordingly, the primary of the induction coil is connected by means of leads 13 and 14 to the controller's headset, and the secondary of the induction coil is connected with tip (T) and ring (R) at the tower. Figure 89 shows that the T and R leads terminate at the loudspeaker in the control tower.

20-41. The operated PTT pushbutton also completes the operating circuit for relay CH in the control tower. The method used for operating this relay is different from any of the previously described circuits. In this case a simplex circuit is used. Figure 90 should enable you to analyze the CH relay operating circuit. You can see that the operation van connects - 24-volt battery potential to the C lead. This C lead is terminated at the center point of two coils. From this midpoint the circuit splits so that the circuit current has two paths to the tower. You know that two paths (branches) are indicative of a parallel circuit. Furthermore, the total resistance of a circuit containing parallel branches is less than the resistance of either of the branches. Reduced resistance results in greater current in the circuit and in greater distance between the van and tower. The two branches are formed into one path again before entering the CH relay. This one lead is also referred to as the C lead.

20-42. The one conductor leading from the opposite side of the CH relay is referred to as G1. The G1 lead is also installed so that it forms a parallel circuit between the tower and the power van. Then, from the power van to the grounded terminal it likewise is a single lead. We learned that one reason for this installation arrangement was to increase circuit current. A second reason for this connecting method is that there was no need for including all additional pair (labeled C and G1) in the cable between the tower and power van. The transmitting pairs (T and R plus T1 and R1) serve as the conducting circuit. This installation method of using a simplex circuit and the transmitting pairs in the cable is valid for a third reason. The simplex coils offer large opposition to the talking current, thus they restrict this ac from bypassing around the tower and van receivers. You should recall the principles of magnetism and how magnetism provides high impedance to ac.

20-43. Figure 90 also indicates that the CH relay operates following your operation of all colored pushbuttons. The same simplex circuit is used to operate the relay following depression of those control buttons. A simplex circuit is also used for operating the AC relays in the tower. Of course, in the latter relay circuits L1 is the - 24-volt source termination lead and lead LG connects to the grounded terminal. Similarly, rather than using the T1 and R1 cable pair, this circuit uses the R2 and T2 cable pair.

20-44. We learned that the controller operates the PAR switch at his position to complete the one-way precision approach radar voice circuit. Foldout 6 shows that this operated PAR switch connects the X and W leads from the controller's headset to the T1 and R1 leads of the cable. Figure 89 also reveals this switch connection. The COM switch operating principle compares to the PAR switch operation. From the simplified schematic of figure 89 you can realize that the circuit difference is that the cable conductors T2 and R2 are connected by the operated COM switch to the X and W leads from the controller's headset.

20-45. *Radio selection.* Normally, the controller is responsible for the radio communications. He places the transfer key in RADIO to complete the equipment connections. The effects of this switch operation can be determined by looking again at foldout 7. The radio selection removes the ground potential to relay WT1, which, in turn, opens the operating circuit of relay WT. Hence, both relays return to the unoperated condition. Contact 3B of relay WT1 places ground to relay TB1 so that talking battery is available to the controller's headset. Contacts 2B and 3 and 5T and 6 of released relay WT connect the controller's receiver with windings of the D repeating coil. Additional windings of this repeating coil are connected to the T and R conductors of the radio equipment at the control tower. Contacts 8B and 9 and 5B and 6 of released relay WT connect the controller's transmitter to a winding of the C repeating coil. The remainder of the repeating coil windings are connected to a 1C pad. This 1C pad and the impedance-matching resistors A, B, and A1 permit adjustments to be made which improve the radio reception and transmission. Contacts 10 and 11T of release relay WT open the operating circuit to a speaker-transfer relay in the radio receiver.

20-46. Your analysis of the controller's radio termination should also show that the connections between the headset and the radio equipment remain when the transfer key is placed in the OFF position. However, in this latter circumstance the TB2 and TB1 relays do not have a connection to ground. Therefore, the transmitter for the controller is unable to function because it has no dc current.

20-47. When you research the technical order that applies to your 302 Switching Unit, you will find many additional schematics and wiring diagrams. They include circuits that function in the same manner as the ones which we have described. For example, you will find relays designated as TB3 and TB4. Each of them serves the assistant controller's headsets. Yet they operate like relays TB1 and TB2, which are shown on foldout 7. Likewise, you will see several additional SL relays. We described the principle for their operation when covering the SL relay of foldout 5. Furthermore, you will find a circuit having an R relay. We did not illustrate it because it operates in the same manner as the R relay of the 1A1 key system; hence, the incoming ac signal from the central office operates it. The operated R relay then starts the LINE lamp flashing. You should now be familiar with flashing lamp circuits, also. The 302 Switching Unit circuits that remain should then become known during your study while on OJT at the organization that is responsible for the equipment.

21. System Maintenance

21-1. To keep communications equipment operating continuously, you must perform high-quality maintenance. Quality work is the result of personal discipline: The airman who has a careless attitude is quite likely to be a trouble making rather than a trouble removing repairman. Equipment should be inspected, corrected, and returned to service as soon as possible. Inspections, testing, and adjustments are best accomplished when programmed. The maintenance schedule should provide for visual and operational inspections within a specific period of time. You are not expected to see each connection each time, yet each should be observed at least once during this scheduled period. This procedure will disclose minor faults that could result in future major faults.

21-2. We are separating system maintenance into four categories: inspections, performance tests, trouble location, and trouble repair.

21-3. **Inspections.** It is important that you consider safety while inspecting the 302 Switching Unit. To illustrate, use care when inspecting connections, because movement of conductors and cables can break connections and can short-circuit terminals. In addition, careless removal of the unit cover may break elements or bend contacts.

21-4. We are listing things to look for when visually inspecting the equipment. However, there may be other features that you will consider or that your supervisor will require.

21-5. *Operations van.* At each position, check the switches for looseness or sticking. In the same manner, determine if the dial and potentiometer have a smooth and positive response. Look at the plugs and jacks for the headset to determine if they are bent or are corroded. Examine the headset cords for worn or exposed areas. Inspect the lamps and lamp jewels for cleanliness. A blackened lamp should be replaced; it may function temporarily, but its life is limited. Observe exposed cable conductors for signs of stress or deterioration.

21-6. *Power van.* Open the equipment cabinet door and look in the fuse holders to determine if there are any spare fuses missing or blown fuses. Inspect for loose screws, broken conductors, missing dust covers, and overheated devices. If a dust cover for a relay is missing, look for crossed contact wires or bent springs. Secondly, determine if the wire wraps at the relay terminals have become loose or if there is dirt on the contacts or terminals. Swing out the equipment racks and take notice of the condition of the wheel and bearings. They should allow the racks to swing out freely from the cabinet. Separate the racks and look for loose or broken connections, loose screws, signs of arcing at relay contacts, missing relay covers, and overheated devices. Check for clean and tight battery connections. Inspect the recorder patch cords and for signs of excessive wear. Look for cables that may be out of place.

21-7. *Control tower.* At each position, check the switches for free movement. Inspect the condition of the lamps and lamp jewels. During rotation of the volume control, see if it is binding. Note also if it is firmly attached to the shaft. At the telephone relay rack, look for loose screws. Then remove the equipment cover and observe the fuse holders for missing spare fuses or blown fuses. Inspect for missing relay covers, burnt devices, arcing between terminals and contacts, and broken connections.

21-8. **Performance Tests.** We know that the individual components are not normally isolated to be tested. They are determined to be functioning by operating the equipment. For example, you learn if the SL relay is in the J53009CR unit, the A relay in the J53033S unit, and the C, PL, and S relays in the J53009CW unit are operating properly by selecting a telephone station for the system and by pressing the LINE key. Of course, operation of the HOLD key insures that the H relays function, and talking to the person at the station reveals that relay TB1 is good. In this manner all components are tested.

21-9. There is no need for us to describe all the performance tests that you make for your type of 302 Switching Unit, because there is a preventive maintenance workcard. set available that gives this information. You will find that these workcards are colored. The green cards include information about performance routines that are done while the equipment is operating. The pink cards describe service routines which consist of work procedures that do not usually require the equipment to be operating. Let us think of what information you should expect these maintenance cards to have! First, they will identify the test. To illustrate: one test determines the condition of the station line between the operations van and control tower. Second, you will be informed of the time that it should take to complete the test. Furthermore, you will be told what controls to operate and what indications should be noticeable if the equipment is operating correctly. For instance: For the station line test you know that you will place the headset plugs into the A and B jacks, put the transfer switch at WIRE and depress the LINE key for the tower circuit. Consequently, LINE or SUPV lamps should illuminate at all operations van positions. Then you must operate the FLASH & RING key. As a result of these actions, you should be able to talk with the tower operator using the tower telephone. Additional test procedures will follow; for example, a return call and the symptoms that accompany it. If you need additional testmen and materials to complete the test, this information is also included. Finally, you are told to record the results of the test and to notify the supervisor of any abnormalities.

NOTE: Notify your supervisor, also, of any discrepancies that you may find in the workcard instructions. These instructions must conform with the maintenance instructions of the current technical orders.

21-10. The loudspeaker 106B performance is an additional test which we will mention. For this test you ask an associate at the GCI station to speak while using the voice signaling circuit. You then listen for a moderate signal. The adjustment for this signal includes the 1C Pad, 89 type resistors, shown in foldout 7. The control that determines their resistance in the circuit is installed in the center of a terminal strip. This control and the loudspeaker volume control are operated together until you reduce any telephone transmitter howl and yet reach the desired listening level.

21-11. Since these performance tests involve personnel at locations where these people may have little time to help you, plan your test carefully. Take advantage of the time when the equipment is not required because of reduced air operations. If you cannot complete all checks at this time, go on to others that you can do, but don't omit any procedure. At a later date perform the one omitted, and do it at a time that is as close to the scheduled time as possible.

21-12. **Trouble Location.** Trouble location in a 302 Switching Unit includes the isolation of the fault to the operations van, to the power van, or to the control tower. We know that each airman should develop methodical procedures for determining troubles. For this reason, we will not list all troubleshooting steps. Similarly, we will not list all the troubles which may occur in a system, because there are many possibilities for each system and there are several systems. Thus, we are disclosing only example trouble procedures.

21-13. Assume that controller number 3 has reported a failure of the fifth LINE PICKUP key to function. Verify the report by pressing the key again. Take note of the lamps at this position and on the other operations van positions. If the lamps fail to operate at this position but light at the other positions,

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then the trouble is isolated to this position. Although it is not probable that both the LINE or SUPV lamps would become open at the same time, you could check each of them. We would assume that the fault may be a connection common to both. Look at your technical order diagrams to see what connection could be common. The station line visual and voice signaling schematic shows a strap between each line lamp; thus, each lamp is grounded by means of a common connection. A visual inspection of this strap should reveal the condition of the connection. However, there are instances where a connection looks acceptable but a resistance check shows it to be a high-resistance connection. The line selection functional schematic shows the same type common ground connection for the SUPV lamps at each operations van position. Further analysis determines that the ground connection in the dark environment lamp control unit (J53009CV) at the power van could not be at fault because it serves the lamps at all positions. The most rapid solution to the problem may be to replace the 623A key unit and lamp socket assembly 61A. If these replacement units correct the failure, you will then tag the faulty units and send them to depot maintenance for repair.

21-14. Note, though, that the preliminary report listed "failure to function." You must determine if there was another trouble symptom, in addition to the lamp failure. In other words, the operated LINE key also must complete the talking circuit between the telephone station and the controller's termination circuit. The schematic of foldout 5 shows that the operation of the SL relay in the power van results in making the contacts that complete this talking circuit, as well as completing the SUPV lamp circuit and the A relay circuit. To see if the SL relays are operating, look at the J53009CR unit.

21-15. A second trouble analysis can be made following the report that the operation of the WHITE pushbutton at the number 1 controller's position results in a steady signal. Now you verify this report and, in addition, press the WHITE pushbutton at the two remaining controller positions. Assume that a steady lamp resulted from their operation, too. These symptoms reveal that the trouble is common to the three positions; probably it is a power van unit trouble. Search of foldout 6 shows that the same ST1 lead starts the flashing circuit operating for all the request and acknowledgment lamps. Hence, you should press one or all of the remaining colored switches. If flashing does not occur, you should consider the power and flashing unit to be at fault or the ST1 lead is open. Conversely, if the operated colored lamps (amber and green) result in a flashing lamp, then our trouble is probably defective contacts on relays K1, BO1, or A1. Replacement of the J53033B unit with a second J53033B unit should reveal if this request and acknowledgment unit is at fault; yet, you must attempt to correct the defective contacts before replacing the wired-in assembly.

21-16. **Trouble Repair.** It is evident from the preceding paragraph that relay contacts can cause circuit failure. Burnishing may be necessary when a contact is coated excessively with film or carbon. Brushing of the contact is the recommended method for removing dirt. Also brush the remaining devices of the equipment unit if they show dirt. The brush that you use must be clean and dry. The method that you use to brush depends on the relay type. To illustrate, on wire spring relays you place the brush below open contacts and then move the brush hairs upward between the contacts. During this upward movement, you must move the brush slightly toward you and then away (sawing type movement). Withdraw the brush without cleaning contacts in another set. Repeat this cleaning several times. Now, reclean your brush in a prescribed cleaning solution, dry it thoroughly, and advance to your next set of dirty contacts. Clean normally closed contacts by inserting a toothpick between the springs. Accordingly, the contacts are held open temporarily.

21-17. Be careful not to touch relay contacts with your fingers or to touch the areas of the brush (or any other cleaning object) that is to rub the relay contact. The oil from your fingers is difficult to remove; therefore it will result in future contact failure.

21-18. Contact burnishing is done in a similar manner to the brushing, in that you use a sawing motion. However, the contacts must be forced against the burnishing blade. You scratch the contacts with the rough edges of the burnishing blade. For this reason, burnishing often results in future contact failure, although it can be useful for the present time. Therefore, burnishing is normally considered as the last method of repair for a relay.

21-19. Clean the surfaces of relay pole pieces, armature, stop pins, etc., with clean paper. You press the two devices being

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cleaned against the paper so that there will be pressure on the paper. Withdrawing the paper will then remove the dirt. If dirt is noted on the withdrawn paper, use a second clean paper and repeat the procedure. Repeat the act until the papers show no stains. When cleaning any device within an equipment unit, examine the unit closely for loose or missing items.

21-20. You have learned that key system relays and switches are adjusted mechanically to meet their electrical requirements. The relays in this 302 Switching Unit are kept operating or repaired in the same manner. We are not going to repeat all the information covered before in this course, and we will not copy that information found in the technical orders for the system. Repeating the major principles that you should remember should be adequate. For example, you readjust a contact spring to a higher tension than the test value indicates. Also, since one mechanical adjustment affects other adjustments, you must observe each adjustment during the test. Use only the circuit requirement table that applies to the specific relay that you are testing and readjusting. Do not use a requirement table that pertains to another manufacturer's relay that has the same nomenclature. Move relay springs and components only after you have found that they are failing completely to perform their function. Keep relays or other apparatus uncovered only as long as necessary to complete the required maintenance.

21-21. Inspection and repair of the telephone for the 302 Switching Unit are done in the same manner as that for telephones in a regular installation.

21-22. After disconnecting a cable from a receptacle, place a protective cap over the receptacle (see fig. 73). When reconnecting a cable to an uncapped receptacle, be sure that the cable and connector are mates. For example, one cable and one receptacle at the power van are labeled REQ & ACK and are colored identically. Thus they are designed to mate. Cup and chain assemblies support some of the cable assemblies to prevent strain damage to the connectors and cables. Insure that the chain lengths are not changed when replacing a cable; or, if the chain length had to be changed during cable removal, make sure the chain is returned to the proper length after cable replacement.

21-23. Perform an operational check of the equipment following replacement of a key unit, a component, or a cable to determine that it has been correctly installed.

Bibliography

Manuscript Figure	*Bell System Practices Reference Number*	*Schematic Diagram Reference Number*
FO 1	518-114-403	69353-01

The above Bell System Practices reference numbers have the following identification: © 1960 American Telephone and Telegraph Co.

Manuscript Figure	*Bell System Practices Reference Number*	*Schematic Diagram Reference Number*
26	518-255-101	49477-01-A1
41	518-114-119	69288-0119
43	518-114-119	69288-0119
FO 2	518-114-119	69288-0107
FO 3	518-410-402	69354-01-A1

The above Bell System Practices reference numbers have the following identification: © American Telephone and Telegraph Co. 1961.

Credit is given to Bell Telephone Laboratories for the above schematic diagram references.

NOTE: None of the references listed in the bibliography above are available from ECI. If you need one of them, borrow it from a local organization that services telephone equipment.

Glossary

Annunciator—Visual signaling device, operated by coil, relay, or relays, and which indicates conditions of associated circuits.

Apparatus—Pieces of equipment used for a common function.

Audio-Frequency Amplifier—Device that increases the amplitude of frequencies that can be detected by the human ear (20 to 20,000 Hertz).

Bimetallic Contacts—Contact springs formed of two dissimilar metals. The metals have different temperature expansion values. So when the temperature changes, the contact springs bend and separate their contacts.

Bridge—Electrical network used to provide a shunt type circuit.

Cable Loop—Go-and-return conductors of a communication circuit; a complete circuit.

Cable Run—Path (position) of a cable that extends from one termination to a second termination.

Common—Connection that is attached to more than one unit, terminal, or wire.

Compatible Unit—Unit designed to work in harmony with associate units.

Crosstalk—Unwanted sound in a communications circuit—sound that results from neighboring communications or power circuits.

Dial Selective Intercommunications Circuit—Circuit that permits intercommunications stations to be selected and signaled by means of a dialed digit or digits.

EBM—Early break then make.

Electromechanical Interrupter—Magnetically operated device for opening and closing an electric circuit rapidly and periodically.

EMB—Early make then break.

GCA—Ground-controlled approach equipment that provides circuits used for providing accurate information for landing aircraft.

GCI—Ground-controlled interception method in which the intercepting weapon is guided to its target by instructions transmitted from the ground.

Impedance Switch—Switch that determines the opposite ratio between the intercommunications set and the interconnecting line.

Interlock—Arrangement that prohibits one action while enabling another or others.

Interoffice—Between stations in the same system.

Key Cable—Cable installed between bridging terminal and telephone.

Manual Intercom—Intercommunications system where control is by persons rather than by automatic devices.

Master Station—The station in an intercommunication system that controls the communications of the organization.

MD—Manufacture discontinued.

Monitor—To check the operation and performance of a system by listening to the output sounds.

Multiple or Multiplicity of Circuit Connections—Two or more circuits connected in parallel.

Network—Two or more interrelated circuits.

Noise Suppression—Limit or reduce noise for a receiver circuit.

Noninductive Winding—A winding constructed so that the magnetic field of one turn cancels the magnetic field of an adjacent turn.

Opaque Material—Material that is neither transparent nor translucent.

Operations Van—Mobile unit where GCA controls and personnel are located that guide and regulate land type aircraft.

Package Unit—Combined units for providing common service to a requesting organization.

PBX (Private Branch Exchange)—Switchboard or automatic apparatus at a headquarters, which permits making outside calls from the local calls between subscribers.

Pigtail—Tightly twisted, bared conductors.

PMEB—Preliminary make with early break.

Pole Piece—Magnetic material formed to control distribution of the magnetic flux around associate devices.

Potentiometer—A three-terminal resistor with sliding contact which provides for variations in electrical circuit voltage.

Preset Conference Circuit—Established circuit for permitting conversations between three or more stations simultaneously.

Radio Communications—Communications system that uses electromagnetic waves for conduction of voice signals.

Rectify—Change alternating current to direct current.

Remote Station—Communications equipment located some distance from the master station (headquarters).

Rotary Stepping Switch—A blank and wiper switch where circuits are completed by the moving wipers, which move only over the bank that is formed like the arc of a circle.

Running Cable—Cable installed between the key telephone units and the bridging terminal.

Short Circuit—Low-resistance connection between two points in a circuit. Also, can be called a shunt.

Station Diversification—Varied distribution of telephone stations.

Stop Pins—Devices on a relay that prevent the moving contact springs from going any further.

Subsequent—Succeeding—following later.

Supervision—Automatic indication of the operation or release of electrical circuits.

Suppression—Elimination of undesirable frequency or group of frequencies.

Terminal Punching—Metal stamping, tinned and designed to make a soldered connection with a wire.

Transient—Instantaneous surge of voltage or current which results from a circuit change.

Vibrator—Electromagnetic device used to change direct current into pulsating current.

Voice Frequencies—Audio range frequencies employed for transmission of speech. They usually range between 200 to 3500 Hertz.

Wire-Line—Telephone communications system that uses wire conductors for the line circuit.

36254 04 S01 7507

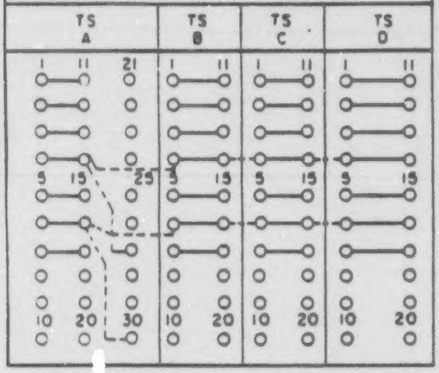
Foldout 1

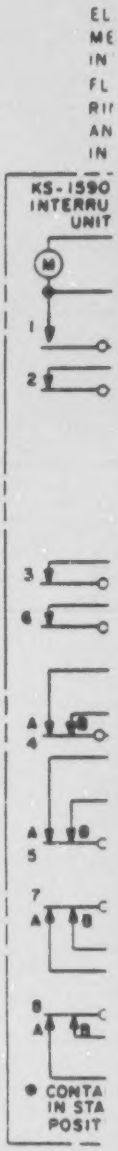
AU GAFS,AL(753280)2100

WARNING FOR CO OR PBX LINES		OPTION
METALLIC RINGING (FURNISHED)		Z
GROUNDED RINGING		Y
INTERRUPTED AUDIBLE SIG (FURNISHED)		X
STEADY AUDIBLE SIGNAL		W
LAMP MAX	MAX 40 LAMPS (FURNISHED)	S
	MAX 80 LAMPS	R

FACTORY STRAPPING OF TERMINAL STRIPS FOR THE 230A KEY TEL UNIT

DOTTED LINE - INTERNAL STRAPPING
SOLID LINE - SURFACE STRAPPING





NOTE 1 FOR THE 230A or B KTU. THE FOLLOWING APPLIES FOR PUNCHINGS 1 THROUGH 20

LINE 1 TERMINATES ON TERMINAL STRIP A
LINE 2 TERMINATES ON TERMINAL STRIP B
LINE 3 TERMINATES ON TERMINAL STRIP C
LINE 4 TERMINATES ON TERMINAL STRIP D
BATTERY AND GROUND TERMINATED ON TERMINAL STRIP A AND STRAPPED INTERNALLY

NOTE 2 MAXIMUM 20 LAMPS PER L LEAD

NOTE 3 WHEN STEADY HOLD LAMP IS REQUIRED INSTEAD OF LAMP WINK. PROVIDE STRAPS AS FOLLOWS

202C & 2020 KTU - TERM 20 AND 29
230A KTU - TERM 20A, B, C, D AND 29A
230B KTU - TERM 20A, B AND 29A
TERM 20C, D, AND 28A

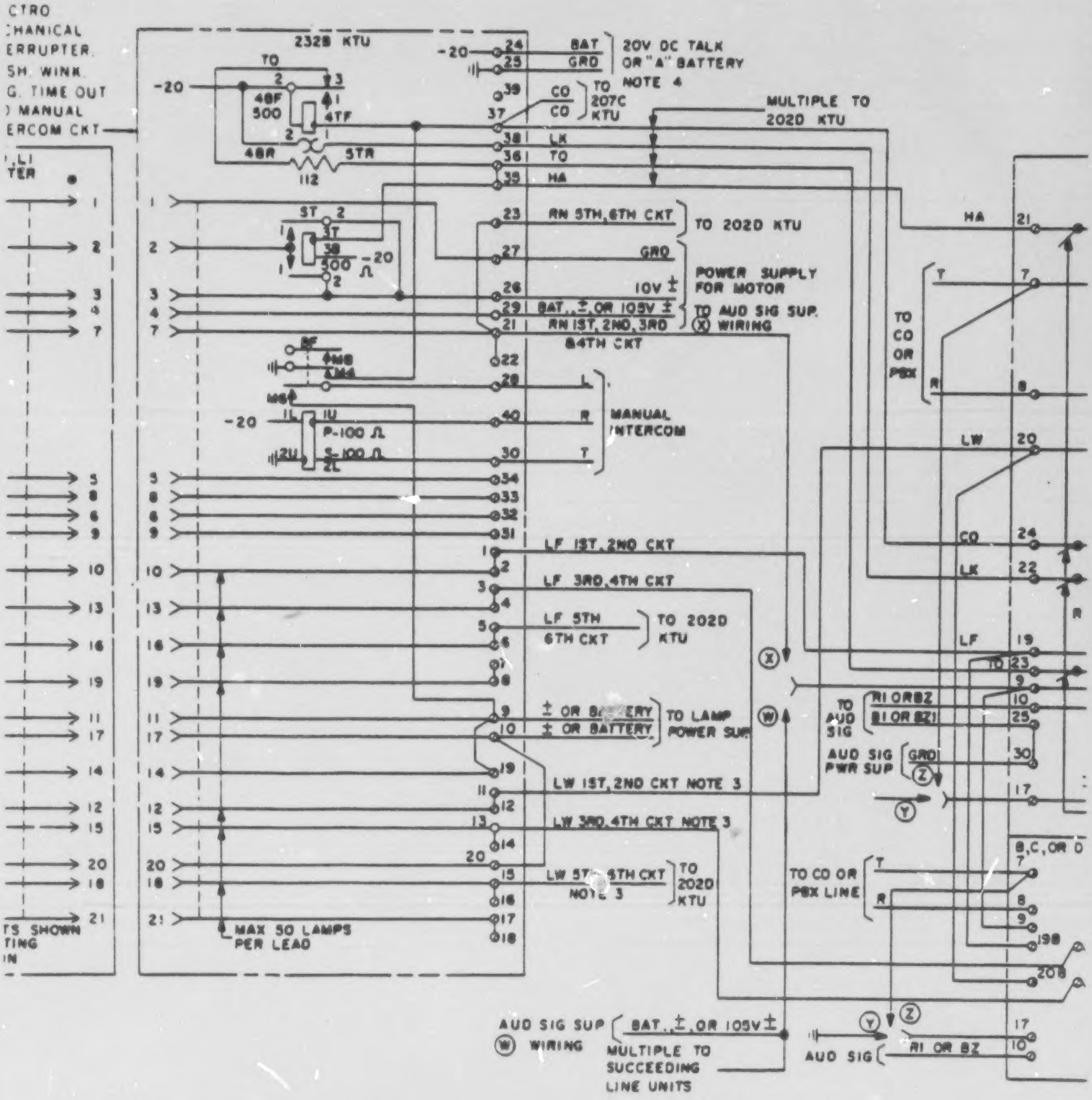
CAUTION: IF PACKAGE INTERRUPTER IS USED TO FURNISH LAMP WINK FOR OTHER SYSTEMS DISCONNECT AND TAPE LW LEADS AT TERMINAL 20 OF EACH LINE CIRCUIT NOT USING THE WINK FEATURE.

NOTE 4 A AND B GROUNDS MUST BE CONNECTED TOGETHER AT POWER SUPPLY

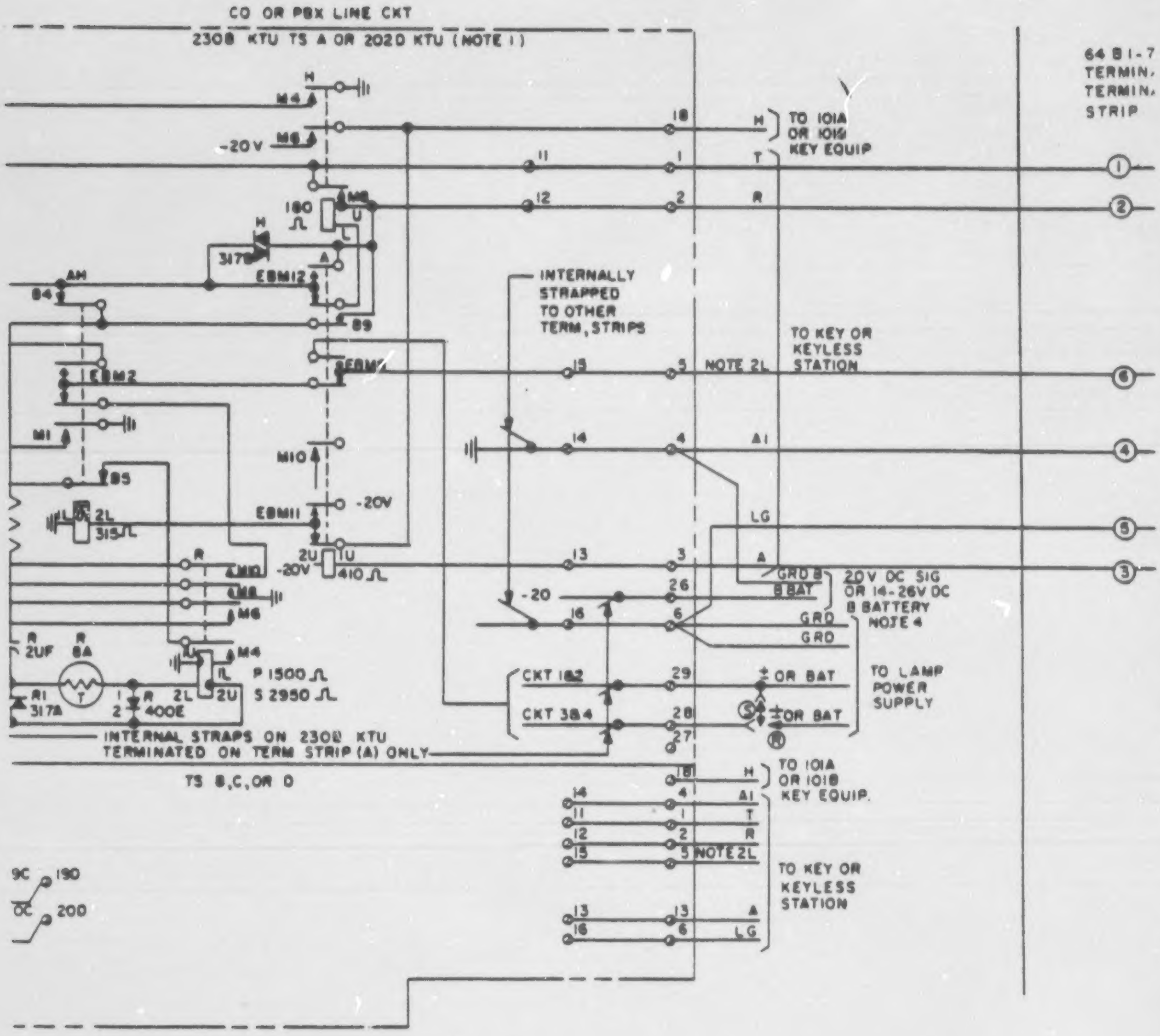
ASSEMBLY OF FOLDOUT 1:

Foldout 1 consists of 6 pages (pages 265 - 270) which should be arranged in the following manner:

265	266	267	268	269	270


CTRO
CHANICAL
ERRUPTER
SH. WINK
G. TIME OUT
MANUAL
ERCOM CKT
TER
232B KTU
TO
-20
48F
500
4TF
48R
5TR
112
ST
3T
3B
500 Ω
-20
BAT
GRD
20V DC TALK
OR "A" BATTERY
NOTE 4
CO
CO
TO
207C
KTU
LK
TO
HA
MULTIPLE TO
202D KTU
RN 5TH, 6TH CKT
TO 202D KTU
GRD
10V ±
POWER SUPPLY
FOR MOTOR
BAT., ±, OR 105V ±
TO AUD SIG SUP.
RN 1ST, 2ND, 3RD
& 4TH CKT
Ⓧ WIRING
MANUAL
INTERCOM
P-100 Ω
S-100 Ω
LF 1ST, 2ND CKT
LF 3RD, 4TH CKT
LF 5TH
6TH CKT
TO 202D
KTU
± OR BATTERY
± OR BATTERY
TO LAMP
POWER SUP
LW 1ST, 2ND CKT NOTE 3
LW 3RD, 4TH CKT NOTE 3
LW 5TH, 6TH CKT
NOTE 3
TO
202D
KTU
MAX 50 LAMPS
PER LEAD
TS SHOWN
TING
HA
TO
CO
OR
PBX
LW
CO
LK
LF
TO
AUD
SIG
RI OR BZ
BI OR BZI
AUD SIG
PWR SUP
GRD
B, C, OR D
TO CO OR
PBX LINE
AUD SIG SUP
Ⓦ WIRING
BAT., ±, OR 105V ±
MULTIPLE TO
SUCCEEDING
LINE UNITS
AUD SIG
RI OR BZ

Foldout 1 continued


CO OR PBX LINE CKT
2308 KTU TS A OR 2020 KTU (NOTE 1)
64 B1-7
TERMIN.
TERMIN.
STRIP
H
M4
-20V
M6
18
H
TO 101A
OR 101B
KEY EQUIP
11
1
T
12
2
R
180
M8
U
L
317B
A
EBM12
AM
B4
89
INTERNALLY
STRAPPED
TO OTHER
TERM. STRIPS
TO KEY OR
KEYLESS
STATION
EBM2
15
5
NOTE 2L
M1
M10
14
4
A1
B5
-20V
EBM11
2L
315
LG
2U
1U
410
13
3
A
R
M10
M8
M6
M4
-20
26
GRD &
B BAT
20V DC SIG
OR 14-26V DC
B BATTERY
NOTE 4
16
6
GRD
GRD
2UF
8A
R1
317A
T
R
400E
2L
2U
P 1500
S 2950
CKT 1&2
29
± OR BAT
TO LAMP
POWER
SUPPLY
CKT 3&4
28
±OR BAT
27
INTERNAL STRAPS ON 2308 KTU
TERMINATED ON TERM STRIP (A) ONLY
TS B,C,OR D
18
H
TO 101A
OR 101B
KEY EQUIP.
14
4
A1
11
1
T
12
2
R
15
5
NOTE 2L
TO KEY OR
KEYLESS
STATION
13
13
A
16
6
LG
9C
190
OC
200
①
②
⑥
④
⑤
③

Foldout 1 continued

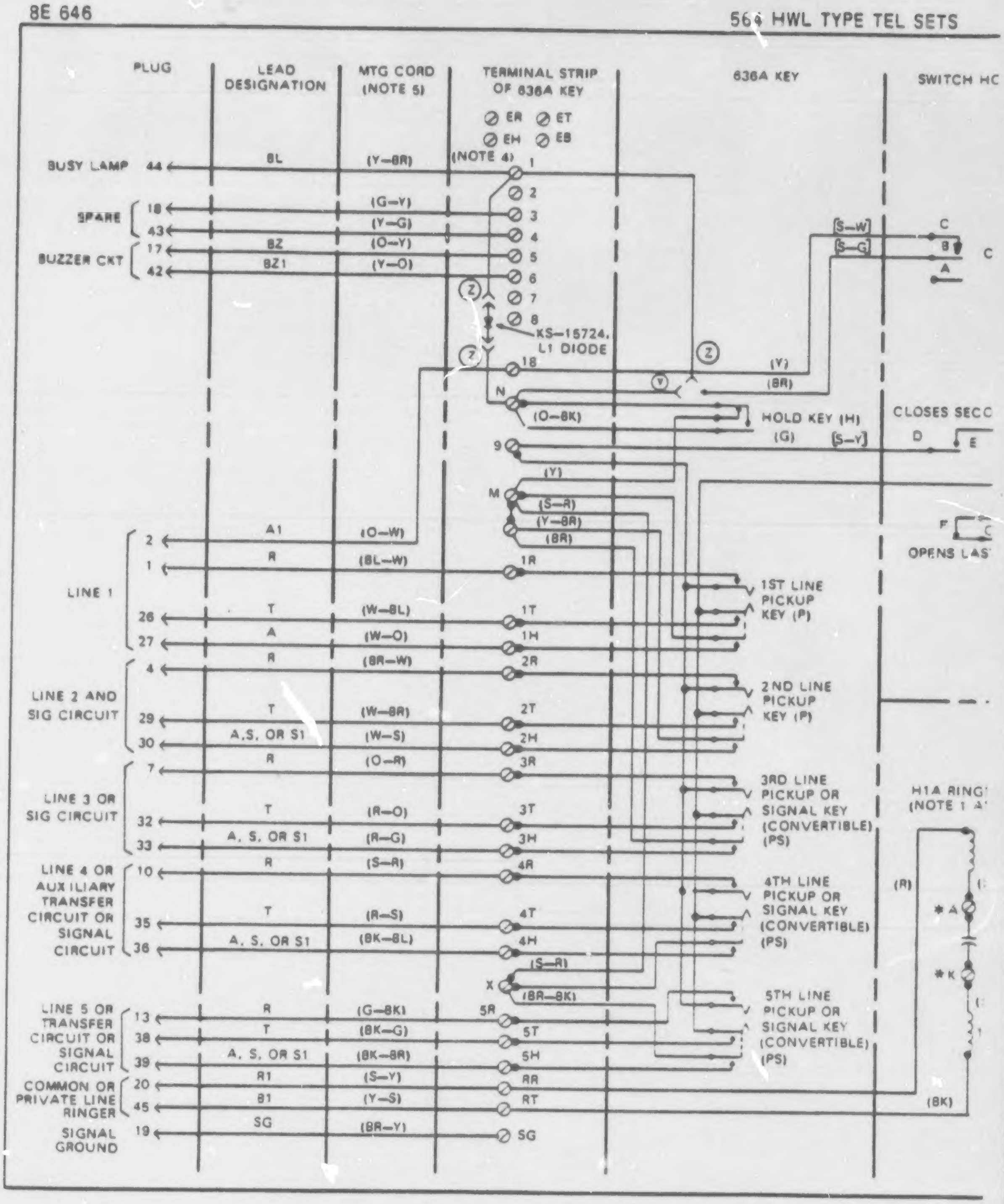
	RUNNING CABLE	RUNNING CABLE	66 A1–25 TERMINAL PINS	66 E 3–25 CONNECTING BLOCK	CONNECTC
A	W-BL	W–BL	①	W–BL	26
	BL-W	BL -W	②	BL–W	1
	G-W	G-W	⑥	⑥	3
	O-W	O -W	④	④	2
	W-G	W-G	⑤	⑤	28
	W-O	W-O	③	③	27

MATCH CONTACT NUMBERS TO TELEPHONE CIRCUIT

Foldout 1 continued

8E 646

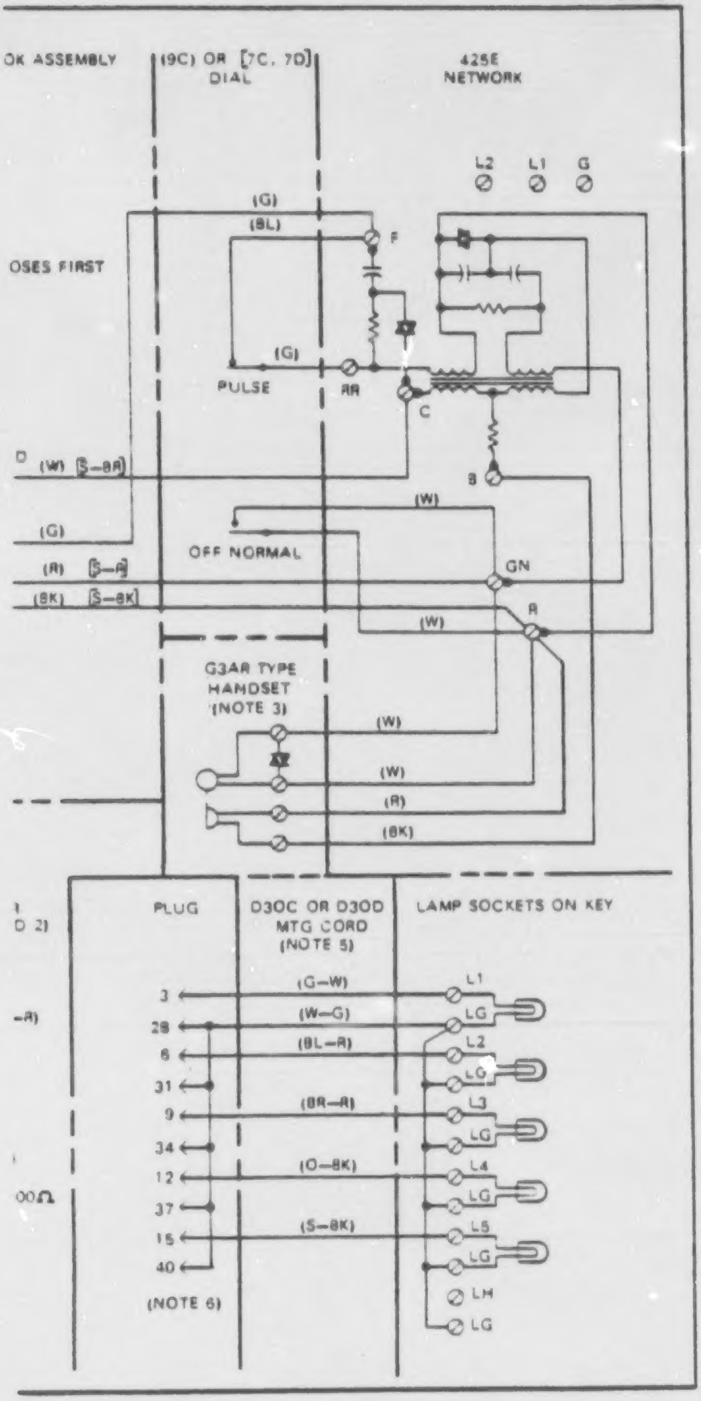
56_ HWL TYPE TEL SETS


PLUG
LEAD DESIGNATION
MTG CORD (NOTE 5)
TERMINAL STRIP OF 636A KEY
636A KEY
SWITCH HC
ER
ET
EH
EB
BUSY LAMP 44
BL
(Y—BR)
(NOTE 4) 1
2
SPARE 18
(G—Y) 3
43
(Y—G) 4
BUZZER CKT 17
BZ
(O—Y) 5
42
BZ1
(Y—O) 6
7
8
Z
KS-15724, L1 DIODE
18
(Y)
(BR)
S—W
S—G
C
B
A
C
N
(O—BK)
HOLD KEY (H)
CLOSES SECC
9
(G)
S—Y
D
E
(Y)
M
(S—R)
(Y—BR)
(BR)
F
OPENS LAST
LINE 1
2
A1
(O—W)
1
R
(BL—W)
1R
26
T
(W—BL)
1T
27
A
(W—O)
1H
1ST LINE PICKUP KEY (P)
LINE 2 AND SIG CIRCUIT
4
R
(BR—W)
2R
29
T
(W—BR)
2T
30
A, S, OR S1
(W—S)
2H
2ND LINE PICKUP KEY (P)
LINE 3 OR SIG CIRCUIT
7
R
(O—R)
3R
32
T
(R—O)
3T
33
A, S, OR S1
(R—G)
3H
3RD LINE PICKUP OR SIGNAL KEY (CONVERTIBLE) (PS)
H1A RINGER (NOTE 1 A
LINE 4 OR AUXILIARY TRANSFER CIRCUIT OR SIGNAL CIRCUIT
10
R
(S—R)
4R
35
T
(R—S)
4T
36
A, S, OR S1
(BK—BL)
4H
4TH LINE PICKUP OR SIGNAL KEY (CONVERTIBLE) (PS)
(R)
*A
*K
X
(S—R)
(BR—BK)
LINE 5 OR TRANSFER CIRCUIT OR SIGNAL CIRCUIT
13
R
(G—BK)
5R
38
T
(BK—G)
5T
39
A, S, OR S1
(BK—BR)
5H
5TH LINE PICKUP OR SIGNAL KEY (CONVERTIBLE) (PS)
COMMON OR PRIVATE LINE RINGER
20
R1
(S—Y)
RR
45
B1
(Y—S)
RT
(BK)
SIGNAL GROUND
19
SG
(BR—Y)
SG

Foldout 1 continued

270

ISSUE 2


OK ASSEMBLY
(9C) OR [7C, 7D] DIAL
425E NETWORK
L2
L1
G
(G)
(BL)
F
OSES FIRST
(G)
PULSE
RR
C
B
D (W) [S–BR]
(W)
(G)
OFF NORMAL
GN
(R) [S–R]
(BK) [S–BK]
R
(W)
G3AR TYPE HANDSET (NOTE 3)
(W)
(W)
(R)
(BK)
PLUG
D30C OR D30D MTG CORD (NOTE 5)
LAMP SOCKETS ON KEY
D 2)
–R)
00Ω
3
28
6
31
9
34
12
37
15
40
(NOTE 6)
(G–W)
(W–G)
(BL–R)
(BR–R)
(O–BK)
(S–BK)
L1
LG
L2
LG
L3
LG
L4
LG
L5
LG
LH
LG

NOTES

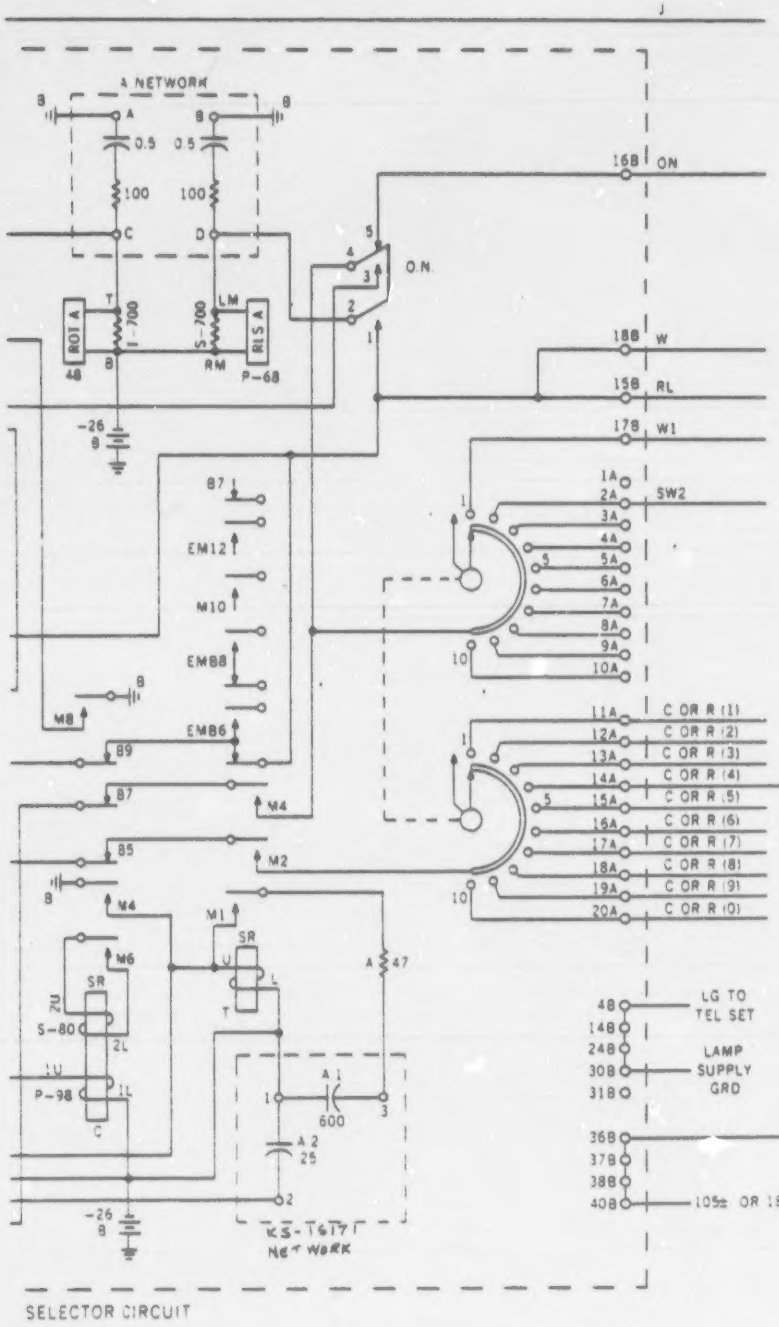
1. CONNECT RINGER WITHOUT CAPACITOR AS COMMON PRIVATE, OR INTERCOMMUNICATING LINE SIGNAL EXCEPT WHERE LOCAL INSTRUCTIONS DIRECT OTHERWISE RINGERS MUST BE WIRED WITH CAPACITOR IN CIRCUIT WHEN COMMON AUDIBLE SIGNAL POWER FAILURE FEATURE IS PROVIDED
2. RINGER LEADS ARE FACTORY WIRED, RED TO RR TERMINAL, BLACK TO RT TERMINAL
3. THE HANDSET MAY BE REPLACED BY ONE CONTAINING AN AMPLIFIER SUCH AS THE G6 TYPE (IMPAIRED HEARING) OR THE G7 TYPE (IMPAIRED SPEECH)
4. BL LEAD CONNECTED TO NETWORK L2 PUNCHING IN LATER MODEL TELEPHONE SETS
5. D30C AND D30D CORDS ARE USED WITH 564HK AND 564HL TELEPHONE SETS RESPECTIVELY
6. STRAP BETWEEN TERMINALS 28, 31, 34, 37, AND 40 IS PROVIDED ON D30D CORD ONLY

* TERMINALS ON NETWORK
( ) INDICATES CURRENT MANUFACTURE CODE
[ ] INDICATES MD CODE

OPTIONS

Ⓜ RINGER CKT
Ⓝ BUZZER CKT
Ⓩ WITH STATION BUSY LAMP
Ⓨ WITHOUT STATION BUSY LAMP

Foldout 1 continued

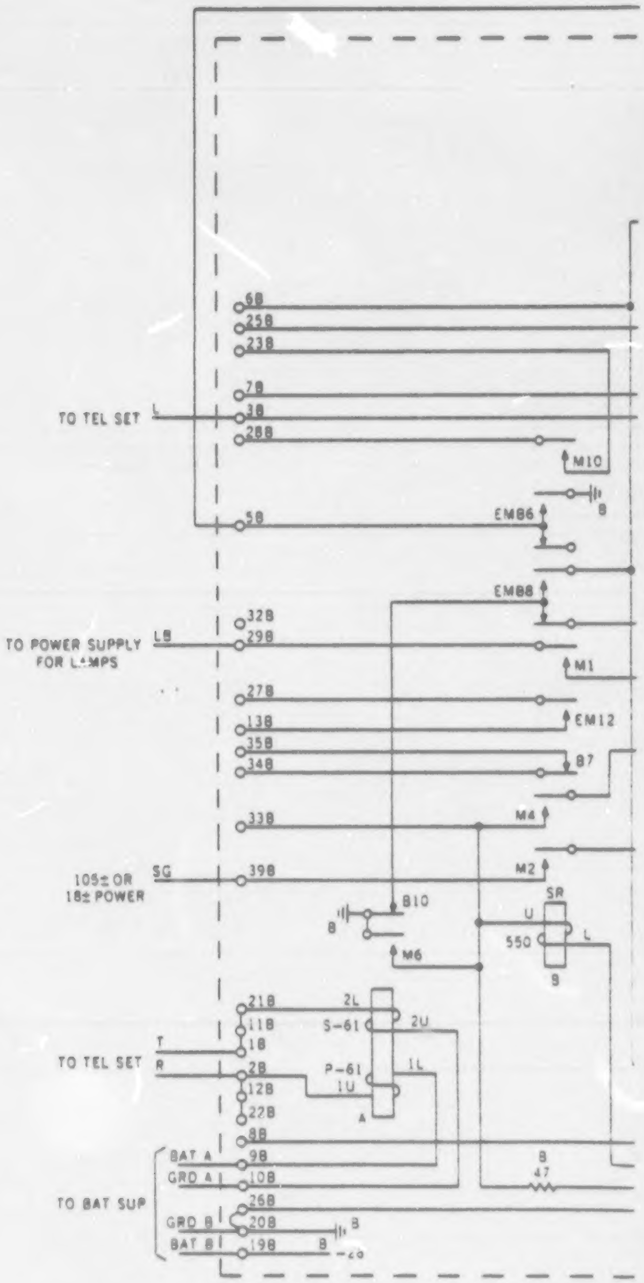

A NETWORK
A
B
C
D
0.5
100
T
LM
ROT A
T-700
S-700
RIS A
48
B
RM
P-68
-26
B
5
4
3
2
1
O.N.
16B
ON
18B
W
15B
RL
17B
W1
1A
2A
SW2
3A
4A
5A
6A
7A
8A
9A
10A
10
B7
EM12
M10
EM88
M8
EM86
B9
B7
M4
B5
M2
M4
M1
M6
SR
2U
S-80
2L
1U
P-98
1L
C
U
L
T
A
47
A 1
600
A 2
25
KS-T6171
NETWORK
11A
C OR R (1)
12A
C OR R (2)
13A
C OR R (3)
14A
C OR R (4)
15A
C OR R (5)
16A
C OR R (6)
17A
C OR R (7)
18A
C OR R (8)
19A
C OR R (9)
20A
C OR R (0)
4B
LG TO
TEL SET
14B
24B
LAMP
SUPPLY
GRD
30B
31B
BELL AT
STA 4
36B
37B
38B
40B
105± OR 18± GRD
SELECTOR CIRCUIT

Foldout 2. Schematic diagram of key system selector circuit.

ASSEMBLY OF FOLDOUT 2:

Foldout 2 consists of 2 pages (pages 271 - 272) which should be arranged in the following manner:

272	271


6B
25B
23B
7B
TO TEL SET
L
3B
28B
M10
B
5B
EM86
EM88
32B
TO POWER SUPPLY FOR LAMPS
LB
29B
M1
27B
13B
EM12
35B
34B
B7
33B
M4
105± OR 18± POWER
SG
39B
M2
SR
B10
B
U
550
L
S
M6
21B
11B
2L
S-61
2U
TO TEL SET
T
1B
R
2B
P-61
1U
1L
12B
22B
A
8B
TO BAT SUP
BAT A
9B
GRD A
10B
B
47
26B
GRD B
20B
B
BAT B
19B
B
-26

Foldout 2 continued

273

ASSEMBLY OF FOLDOUT 3:

Foldout 3 consists of 6 pages (pages 273 to 278) which should be arranged according to Figure 1.

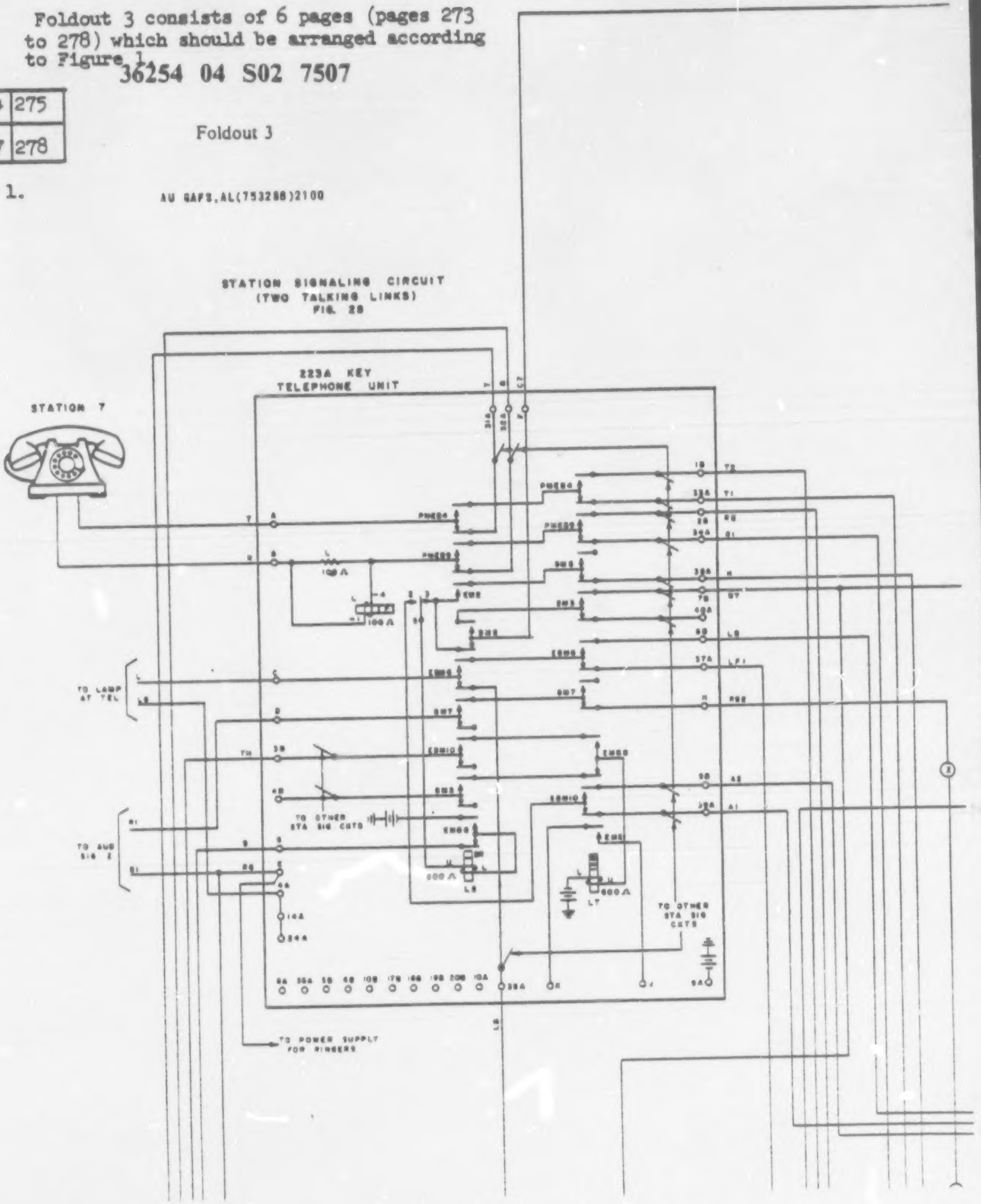
36254 04 S02 7507

273	274	275
276	277	278

Figure 1.

Foldout 3

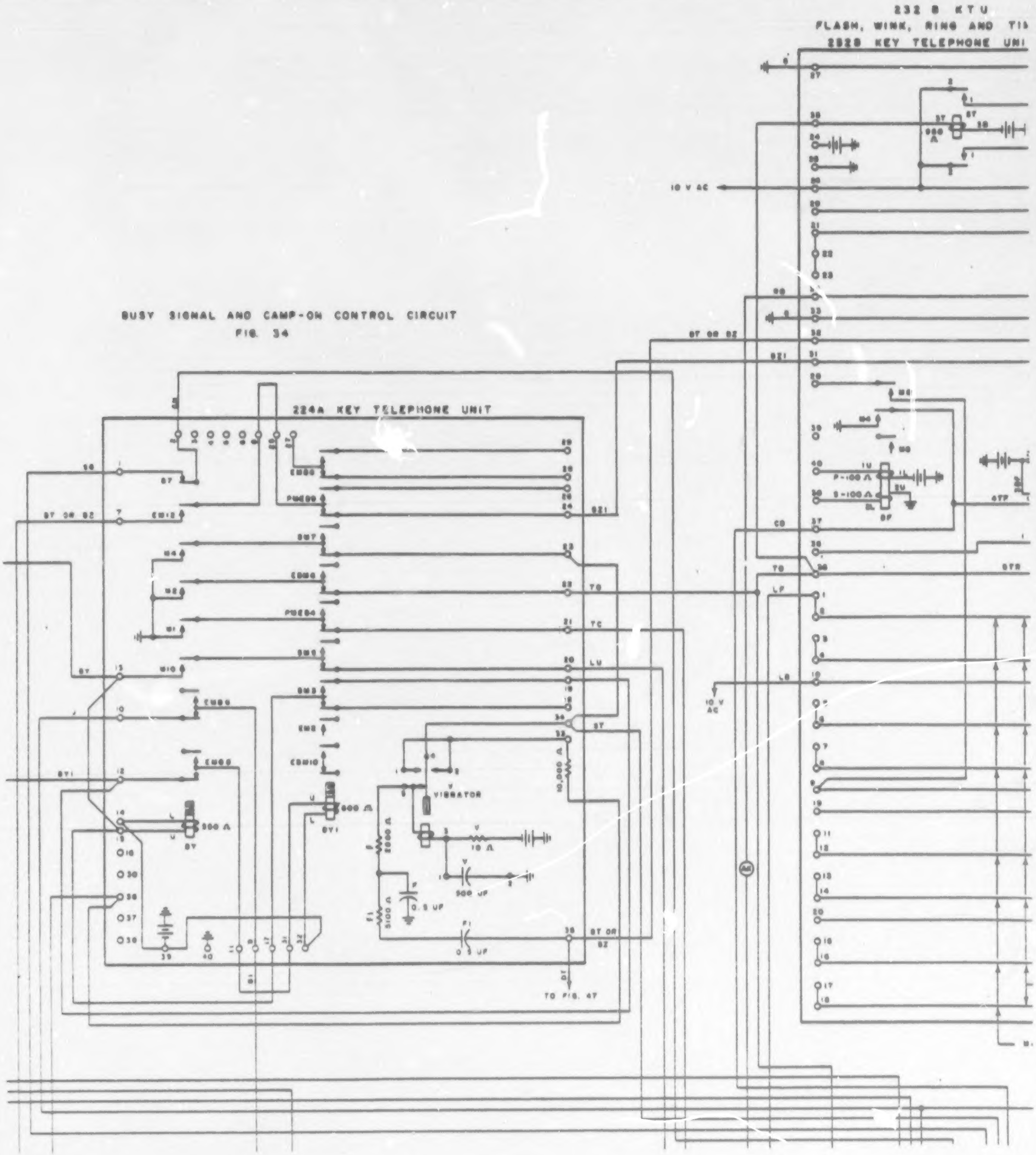
AU GAFS,AL(753288)2100



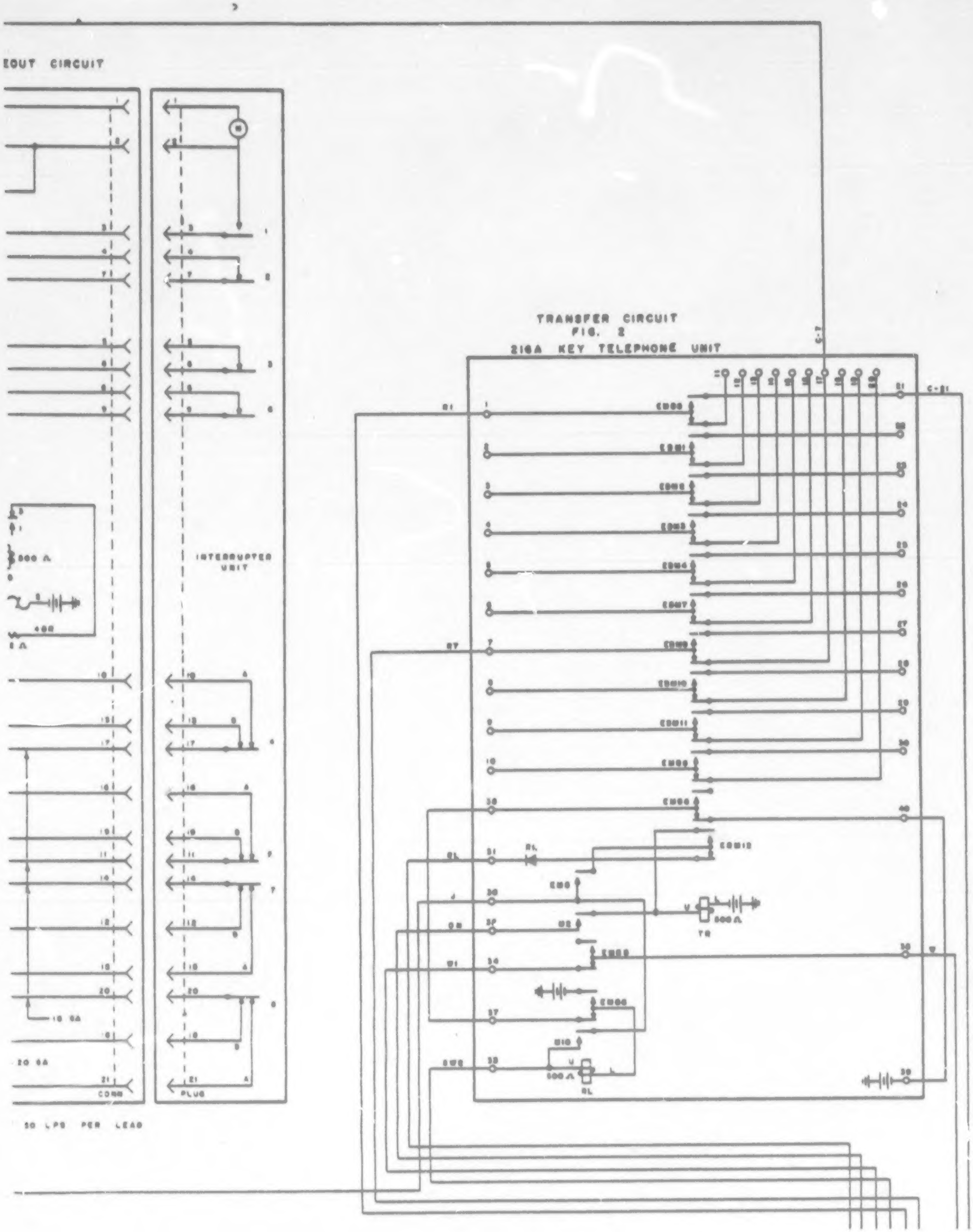
STATION SIGNALING CIRCUIT
(TWO TALKING LINKS)
FIG. 28

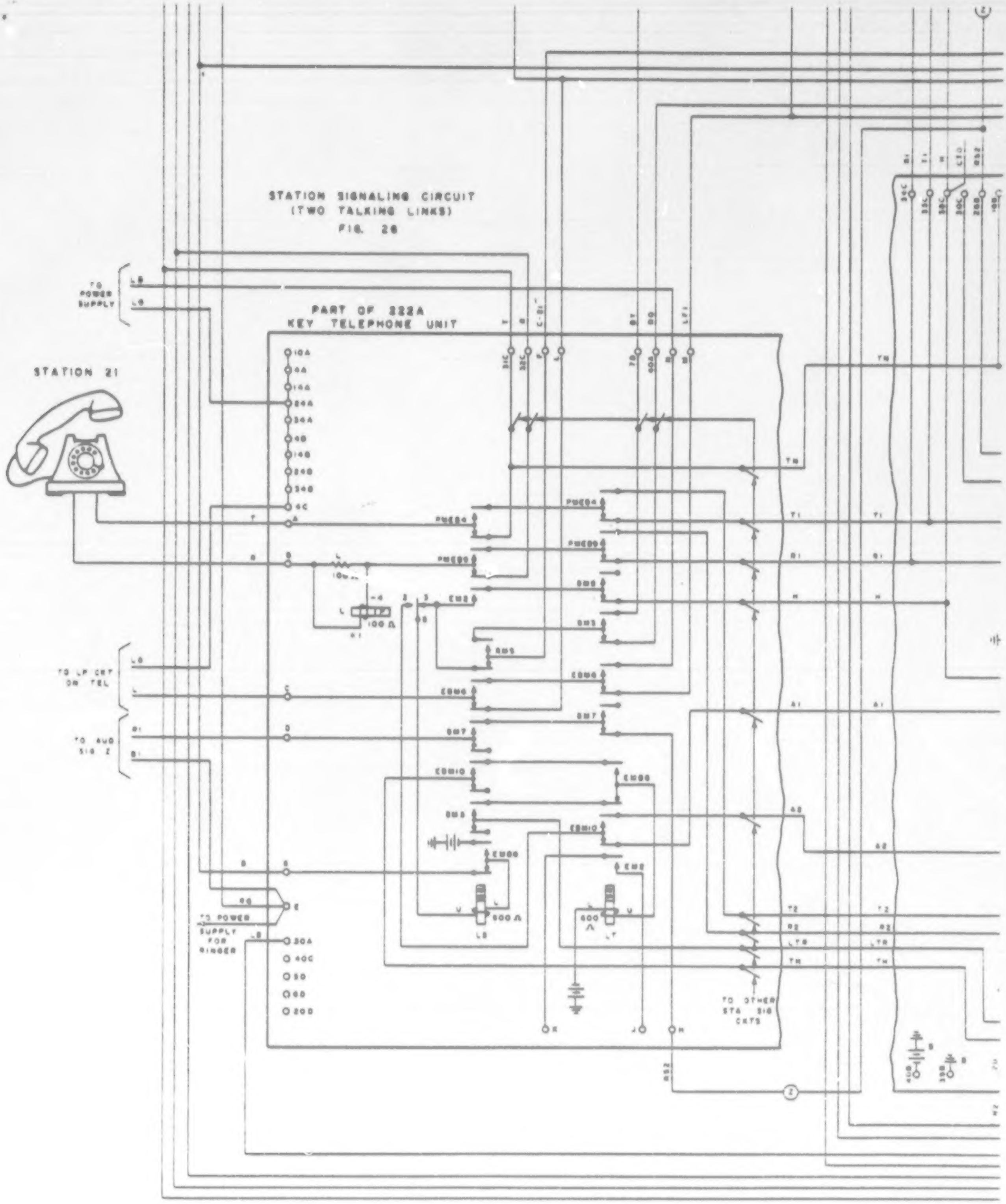
STATION 7
223A KEY
TELEPHONE UNIT
TO LAMP AT TEL
TO AUD SIG
TO OTHER STA SIG CKTS
TO POWER SUPPLY FOR RINGERS
100 Ω
600 Ω
LS
LT

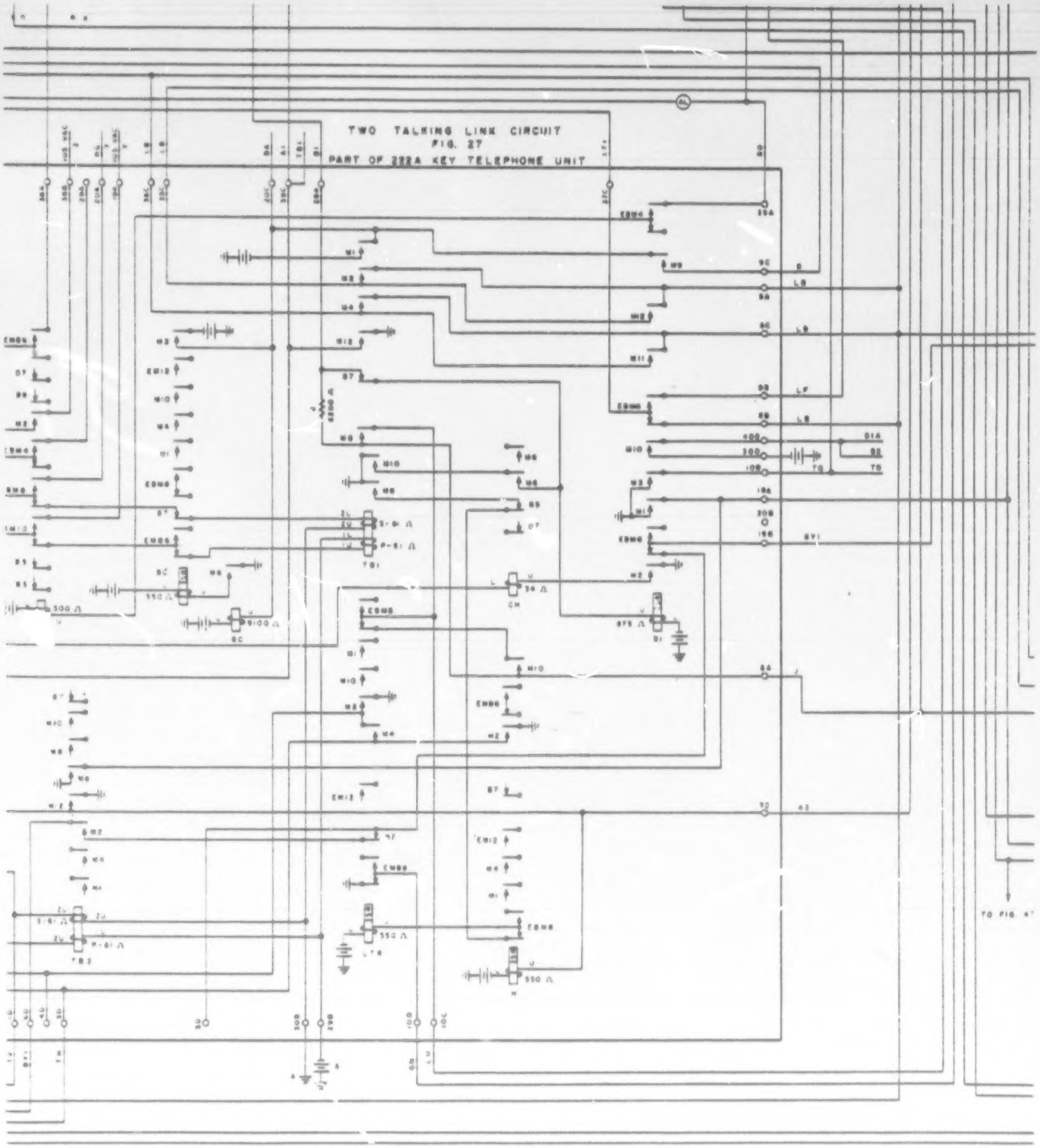
274


232 B KTU
FLASH, WINK, RING AND TI
232B KEY TELEPHONE UNI
BUSY SIGNAL AND CAMP-ON CONTROL CIRCUIT
FIG. 34
224A KEY TELEPHONE UNIT
10 V AC
VIBRATOR
10,000 Ω
300 Ω
600 Ω
2000 Ω
5100 Ω
10 Ω
0.5 UF
500 UF
P-100 Ω
S-100 Ω
ST OR SZ
SZ1
TG
TC
LU
LF
LS
ST
STR
TO FIG. 47

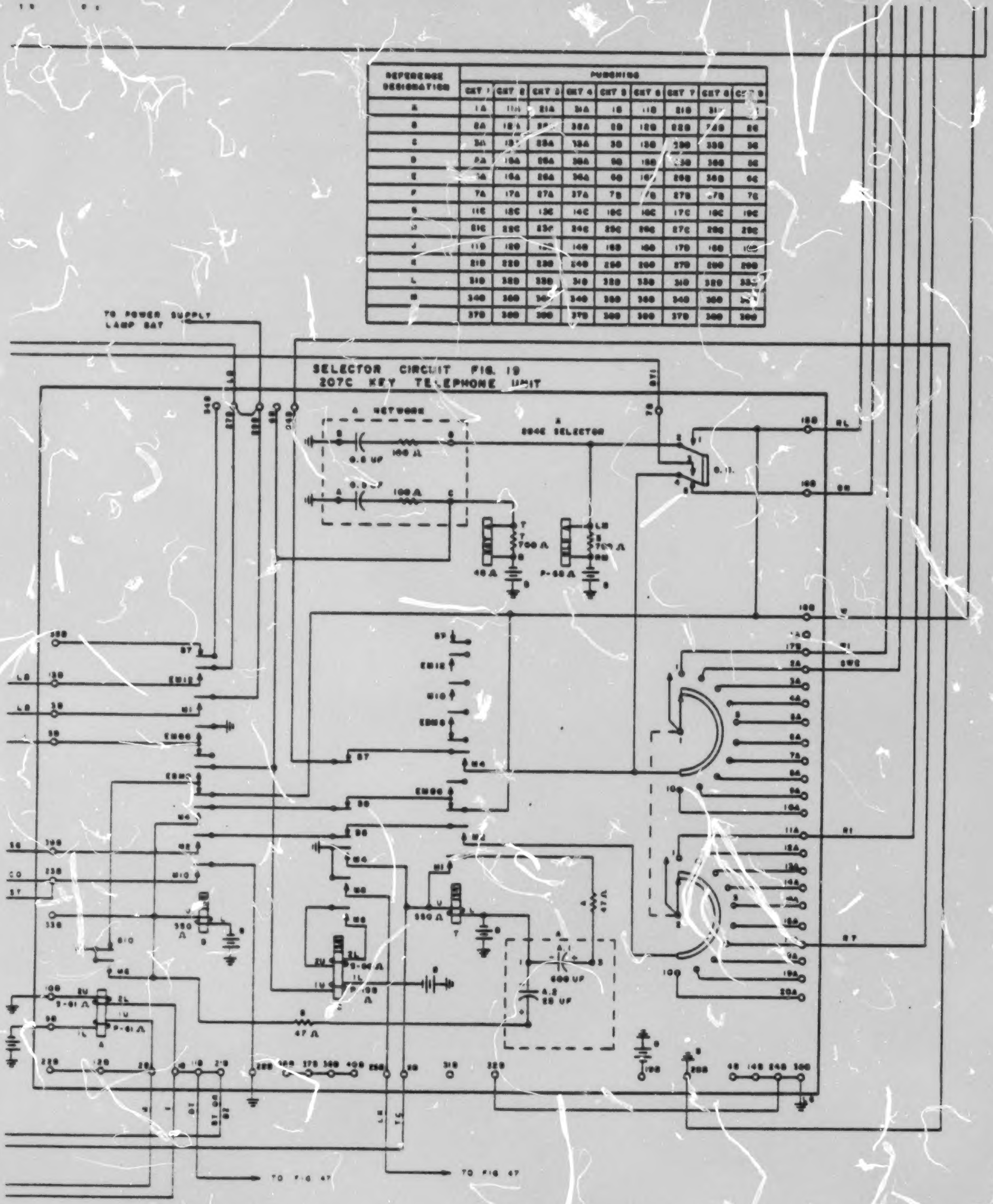
Foldout 3 continued


EOUT CIRCUIT
INTERRUPTER UNIT
300 Ω
CONN
PLUG
50 LPS PER LEAD
10 GA
20 GA
TRANSFER CIRCUIT
FIG. 2
216A KEY TELEPHONE UNIT
C-7
C-21
CDM12
TR
500 Ω
RL



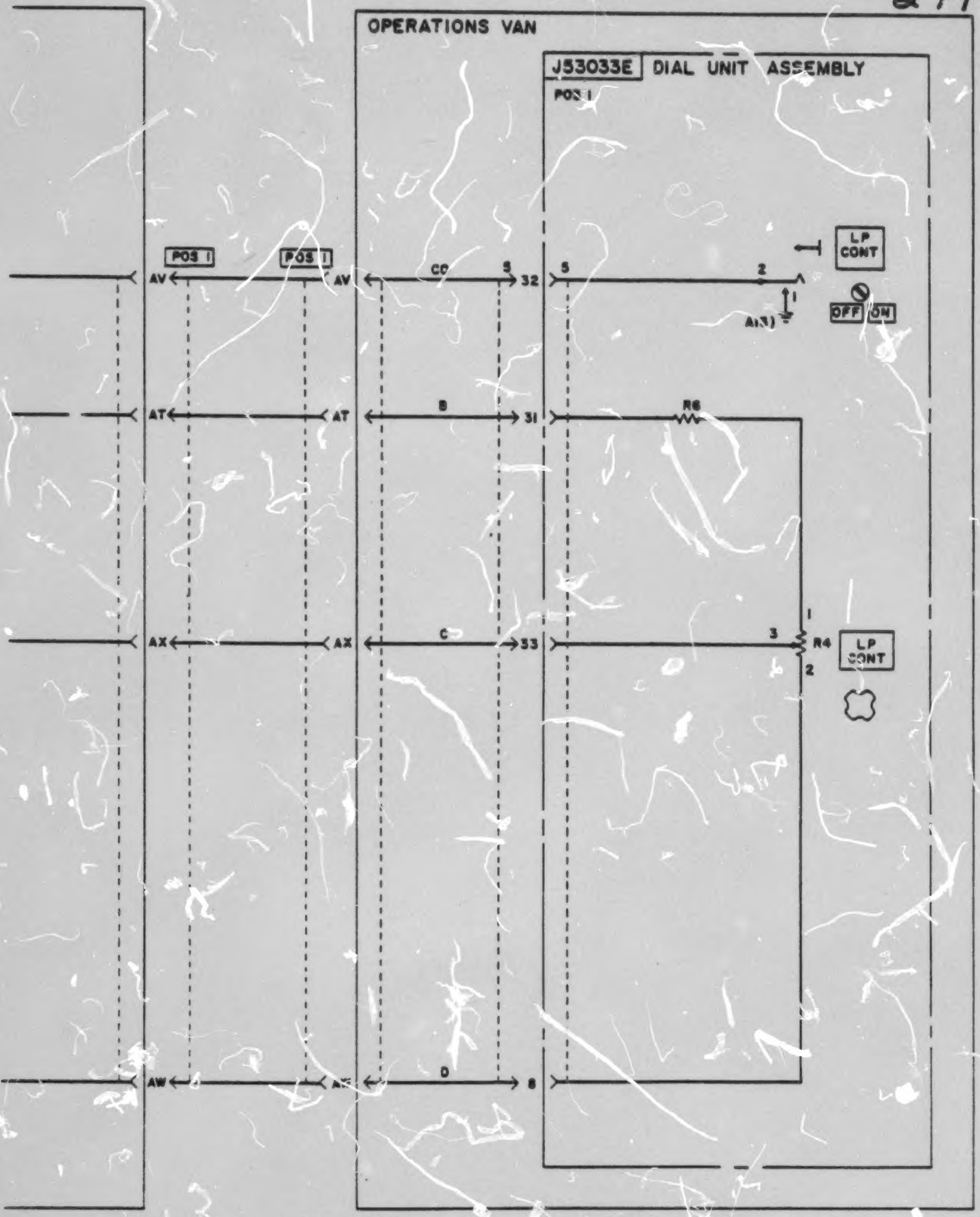

TWO TALKING LINK CIRCUIT
FIG. 27
PART OF 222A KEY TELEPHONE UNIT
TO FIG 47

Foldout 3. Schematic diagram of 6A key system circuits.


SELECTOR CIRCUIT FIG. 19
207C KEY TELEPHONE UNIT
TO POWER SUPPLY LAMP BAT
A NETWORK
0.5 UF
100 Ω
A
204C SELECTOR
O.N.
700 Ω
46 Ω
P-60 Ω
RL
SR
BWG
R1
ST
LG
SG
CO
390 Ω
47 Ω
600 UF
25 UF
TO FIG 47
TO FIG 47

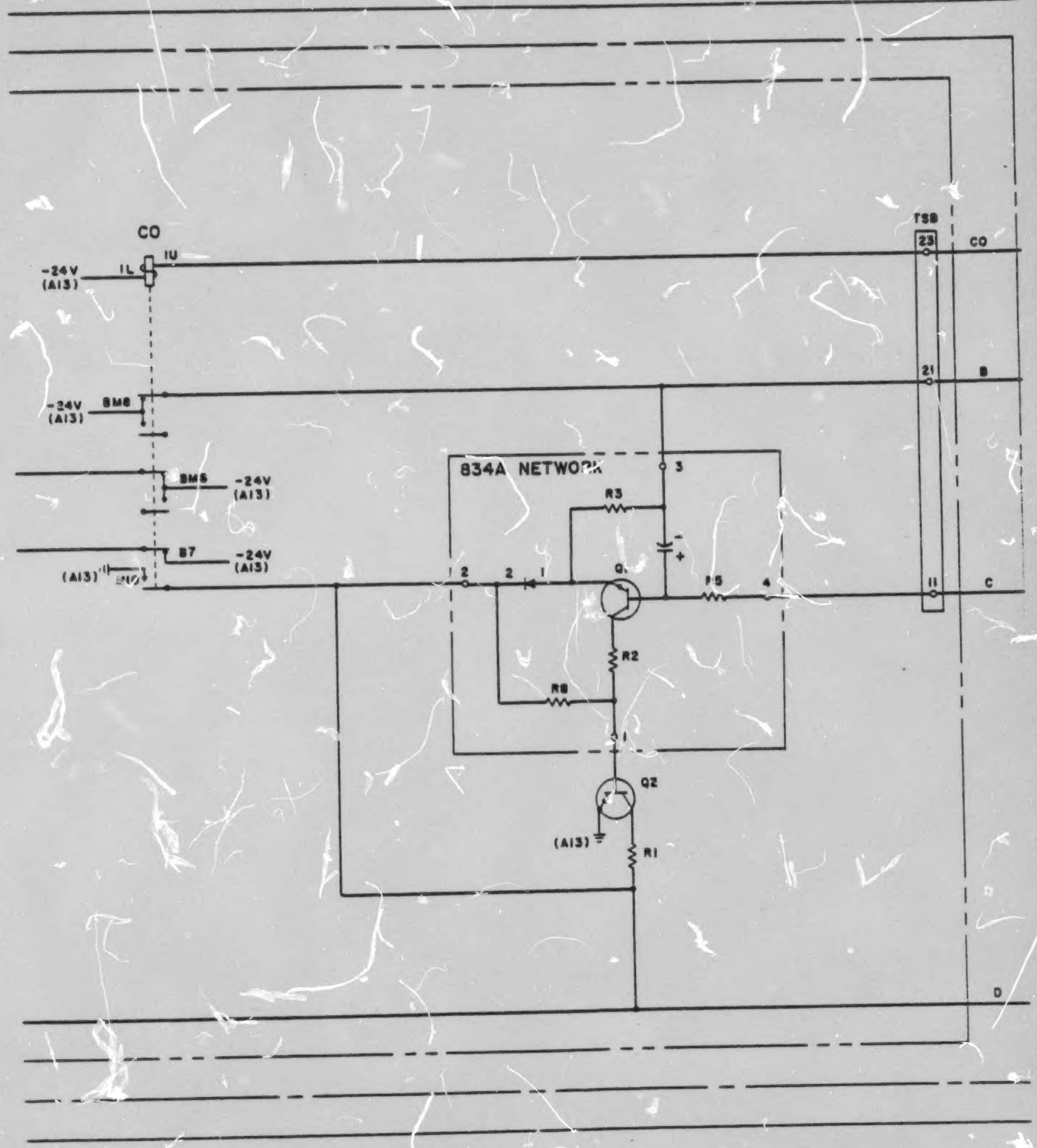
REFERENCE DESIGNATION	PUNCHING								
	CKT 1	CKT 2	CKT 3	CKT 4	CKT 5	CKT 6	CKT 7	CKT 8	CKT 9
A	1A	11A	21A	31A	1B	11B	21B	31B	[illegible]
B	2A	12A	[illegible]	32A	2B	12B	22B	32B	2C
C	3A	13A	23A	33A	3B	13B	23B	33B	3C
D	5A	15A	25A	35A	5B	15B	25B	35B	5C
E	[illegible]	16A	26A	36A	6B	16B	26B	36B	6C
F	7A	17A	27A	37A	7B	17B	27B	37B	7C
G	11C	12C	13C	14C	15C	16C	17C	18C	19C
H	21C	22C	23C	24C	25C	26C	27C	28C	29C
J	11D	12D	[illegible]	14D	15D	16D	17D	18D	19D
K	21D	22D	23D	24D	25D	26D	27D	28D	29D
L	31D	32D	33D	31D	32D	33D	31D	32D	33D
M	34D	35D	36D	34D	35D	36D	34D	35D	36D
	37D	38D	39D	37D	38D	39D	37D	38D	39D

Foldout 3 continued


OPERATIONS VAN
J53033E DIAL UNIT ASSEMBLY
POS 1
POS 1
POS 1
LP CONT
OFF ON
A(3)
AV
AV
CO
5
32
5
2
1
AT
AT
B
31
R6
AX
AX
C
33
3
1
R4
2
LP CONT
AW
AW
D
8

Foldout 4. Dark environment lamp control circuit.

Assembly directions for Foldout 4 on page 281.

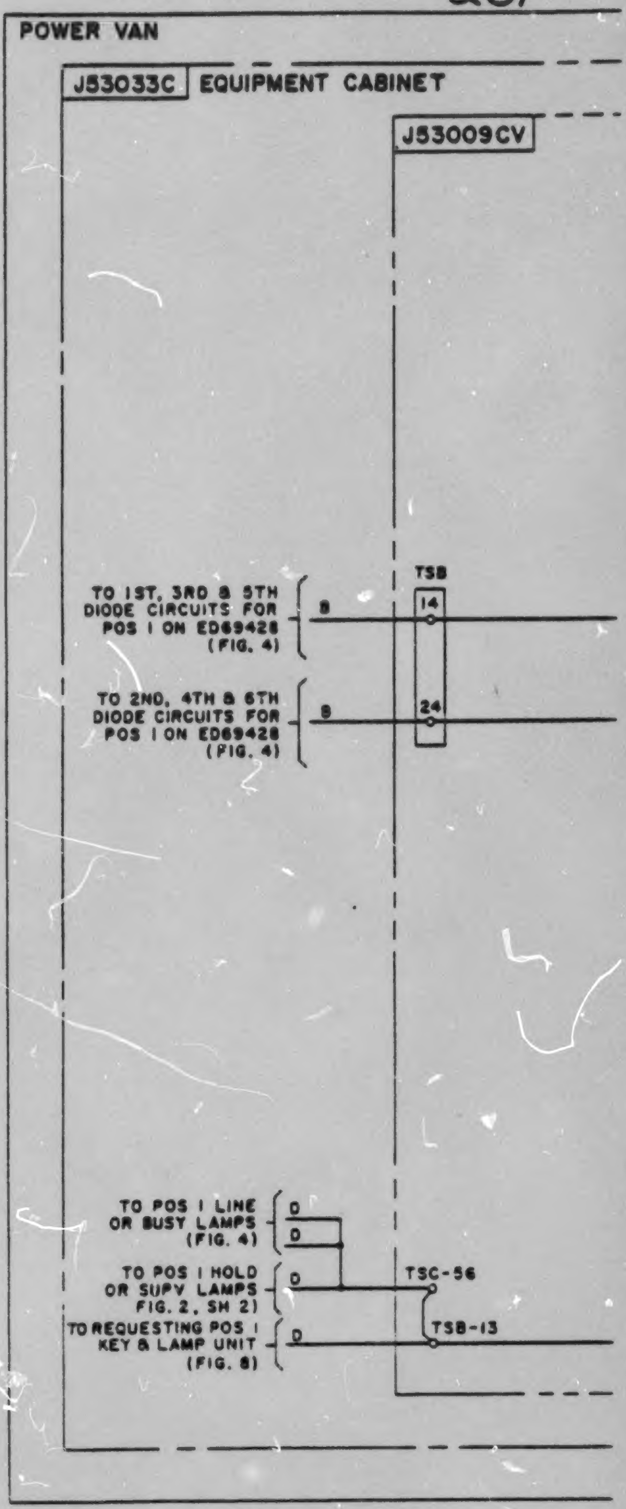

CO
1U
1L
-24V (A13)
BM8
-24V (A13)
BM5
-24V (A13)
B7
-24V (A13)
(A13)
834A NETWORK
3
R3
2
2
1
Q1
R5
4
R2
R8
1
Q2
(A13)
R1
TSB
23
CO
21
B
11
C
D

Foldout 4 continued

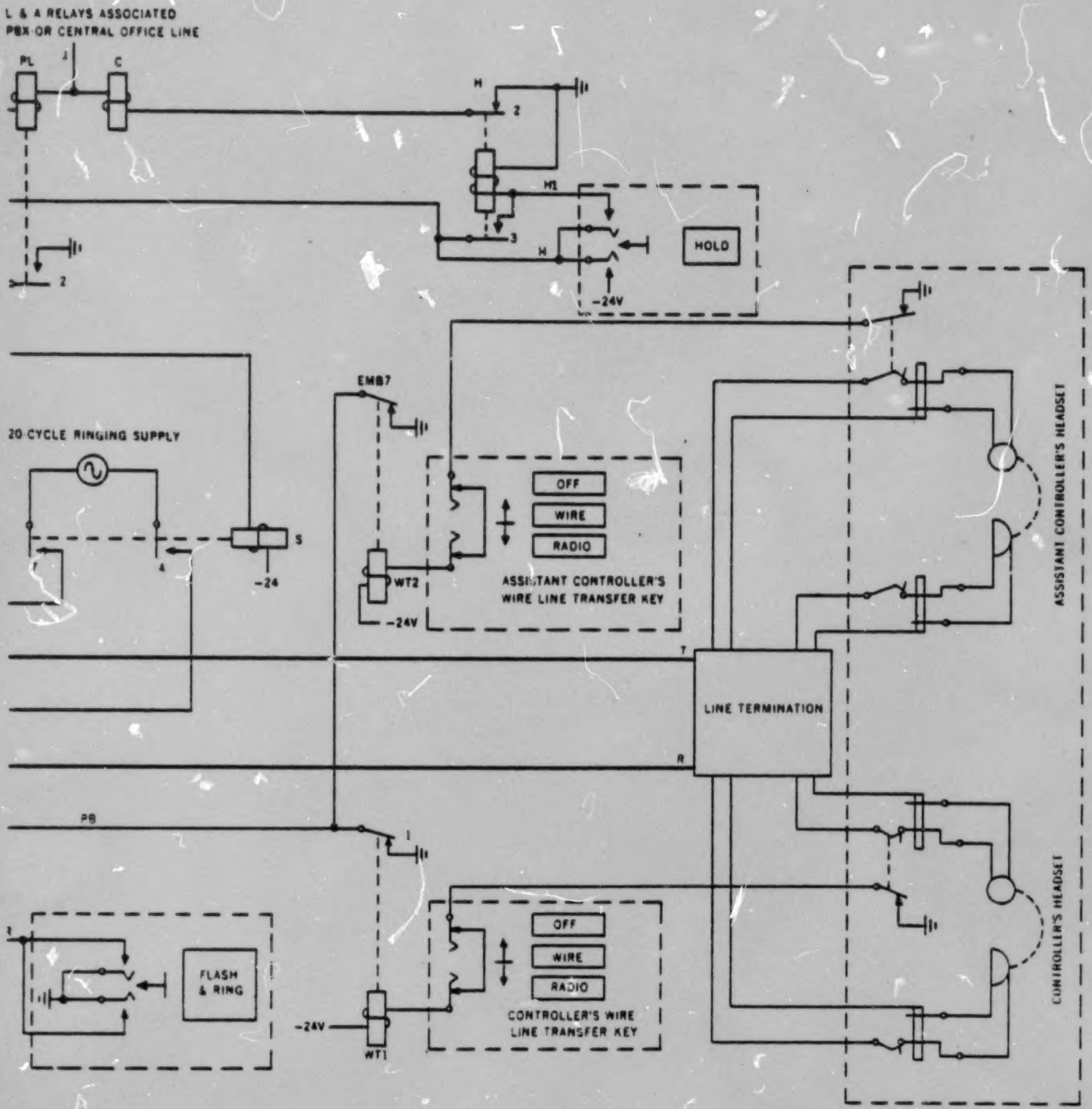
ASSEMBLY OF FOLDOUT 4:

Foldout 4 consists of 3 pages (pages 279 to 281) which should be arranged in the following manner:

281	280	279


POWER VAN
J53033C
EQUIPMENT CABINET
J53009CV
TSB
14
24
TO 1ST, 3RD & 5TH DIODE CIRCUITS FOR POS 1 ON ED69428 (FIG. 4)
B
TO 2ND, 4TH & 6TH DIODE CIRCUITS FOR POS 1 ON ED69428 (FIG. 4)
B
TO POS 1 LINE OR BUSY LAMPS (FIG. 4)
D
D
TO POS 1 HOLD OR SUPV LAMPS FIG. 2, SH 2)
D
TSC-56
TO REQUESTING POS 1 KEY & LAMP UNIT (FIG. 8)
D
TSB-13

Foldout 4 continued

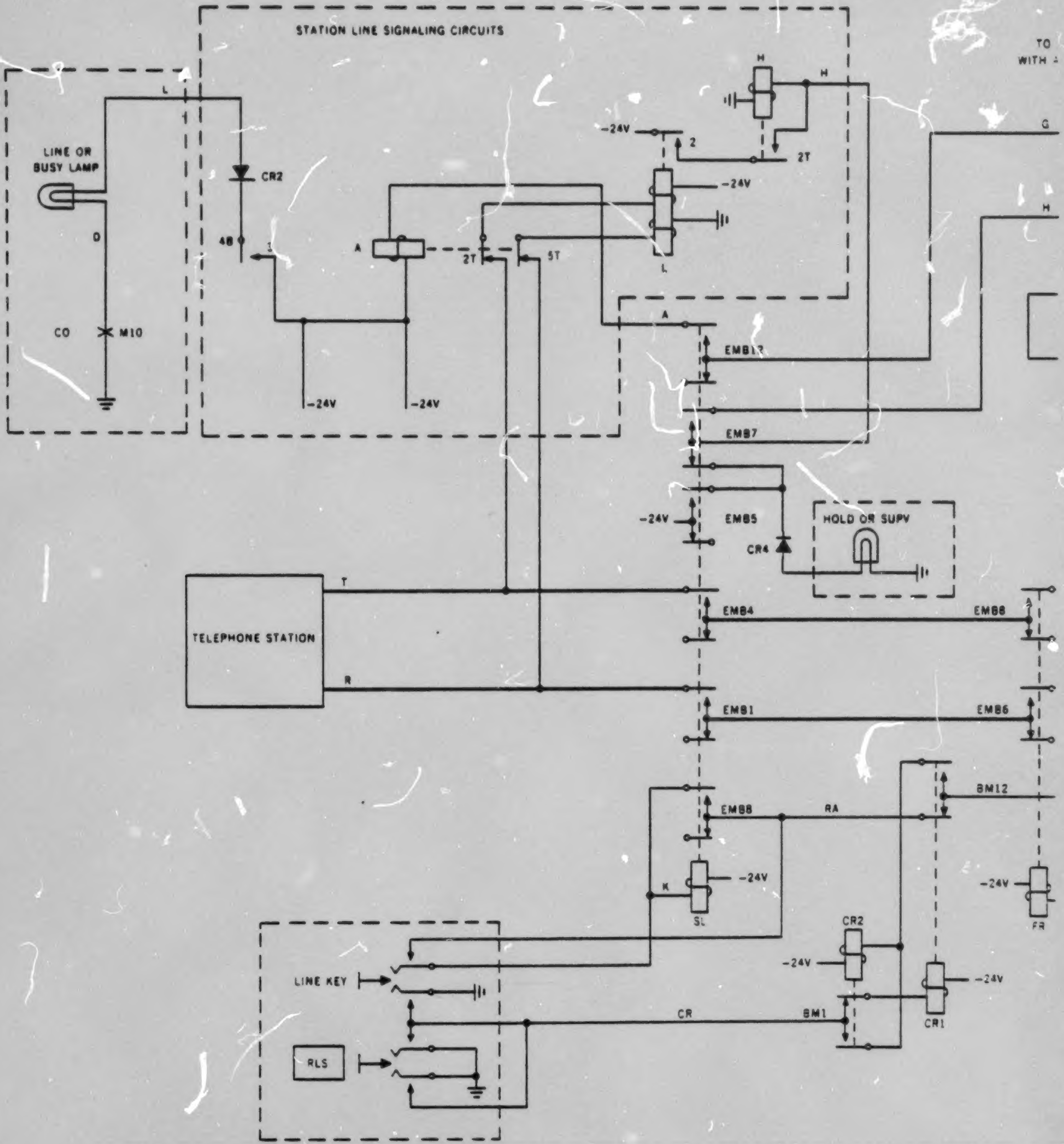

L & A RELAYS ASSOCIATED
PBX OR CENTRAL OFFICE LINE
PL
J
C
H
2
H1
3
H
HOLD
-24V
2
EMB7
20-CYCLE RINGING SUPPLY
S
-24
4
OFF
WIRE
RADIO
WT2
-24V
ASSISTANT CONTROLLER'S
WIRE LINE TRANSFER KEY
T
LINE TERMINATION
R
PB
1
ASSISTANT CONTROLLER'S HEADSET
CONTROLLER'S HEADSET
2
FLASH & RING
-24V
WT1
OFF
WIRE
RADIO
CONTROLLER'S WIRE
LINE TRANSFER KEY

Foldout 5. Schematic diagram for line selection equipment.

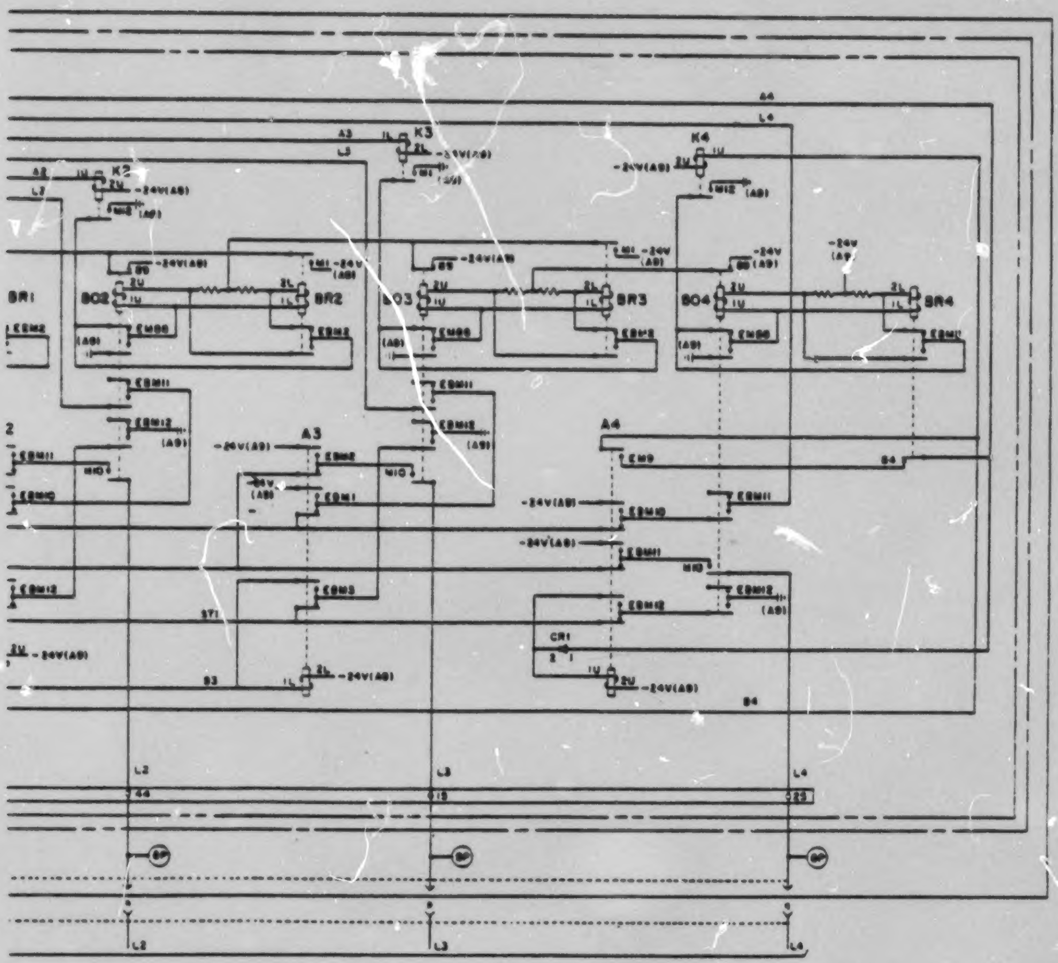
ASSEMBLY OF FOLDOUT 5:

Foldout 5 consists of 2 pages (pages 282 and 283) which should be arranged in the following manner:

283	282


STATION LINE SIGNALING CIRCUITS
TO
WITH
LINE OR BUSY LAMP
L
D
CO
M10
CR2
4B
1
A
2T
5T
L
H
2
2T
-24V
G
H
A
EMB12
EMB7
EMB5
CR4
HOLD OR SUPV
TELEPHONE STATION
T
R
EMB4
EMB8
EMB1
EMB6
BM12
EMB8
RA
K
SL
FR
CR2
CR1
LINE KEY
RLS
CR
BM1

Foldout 5 continued

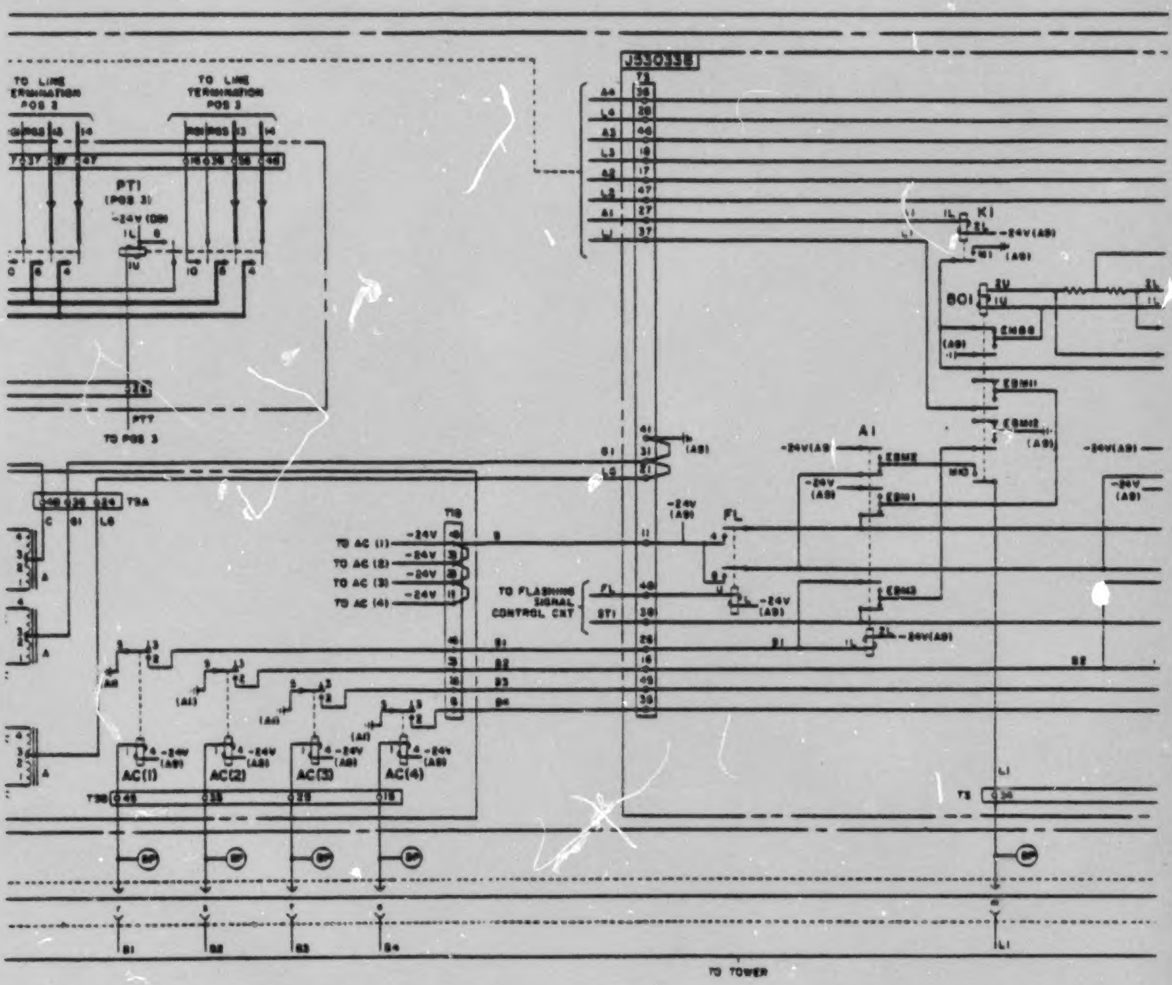

K2
K3
K4
A3
L3
A4
L4
BR1
BO2
BR2
BO3
BR3
BO4
BR4
-24V(A9)
CR1
B3
B4
L2
L3
L4

Foldout 6. Schematic diagram for request and acknowledgment equipment.

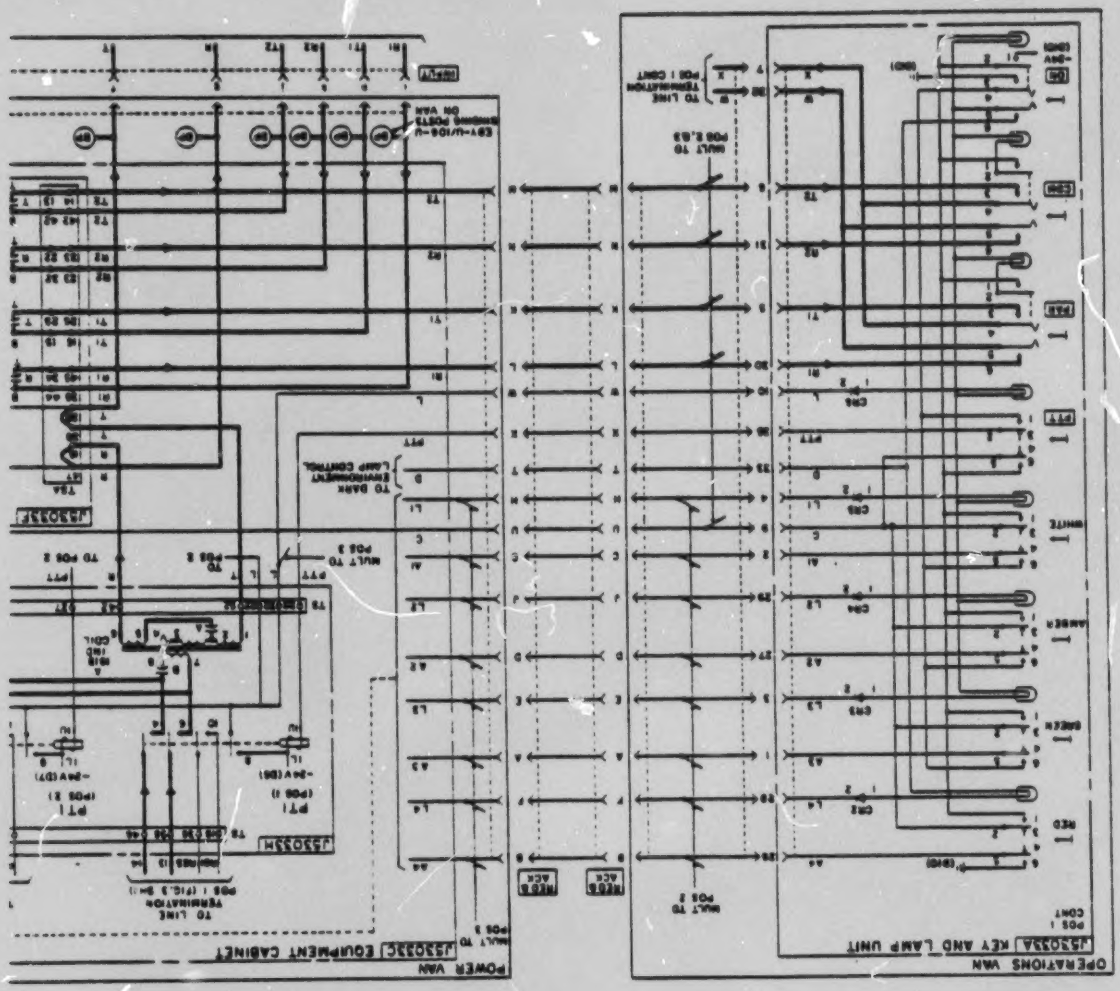
ASSEMBLY OF FOLDOUT 6:

Foldout 6 consists of 3 pages (pages 284 to 286) which should be arranged in the following manner:

286	285	284


TO LINE TERMINATION POS 2
TO LINE TERMINATION POS 3
PT1 (POS 3)
-24V (DB)
PTT
TO POS 3
T2
A4
L4
A3
L3
A2
L2
A1
L1
K1
-24V (AB)
801
A1
FL
TSA
TO AC (1)
TO AC (2)
TO AC (3)
TO AC (4)
-24V
TO FLASHING SIGNAL CONTROL CKT
AC(1)
AC(2)
AC(3)
AC(4)
TSB
B1
B2
B3
B4
TO TOWER

Foldout 6 continued


POWER VAN
J530332C EQUIPMENT CABINET
OPERATIONS VAN
J530333A KEY AND LAMP UNIT
TO LINE TERMINATION
MULT TO POS 2
TO DARK ENVIRONMENT LAMP CONTROL
PTT
WHITE
AMBER
GREEN
RED
REQ ACK

Foldout 6 continued

36254 04 S03 7507

Foldout 7

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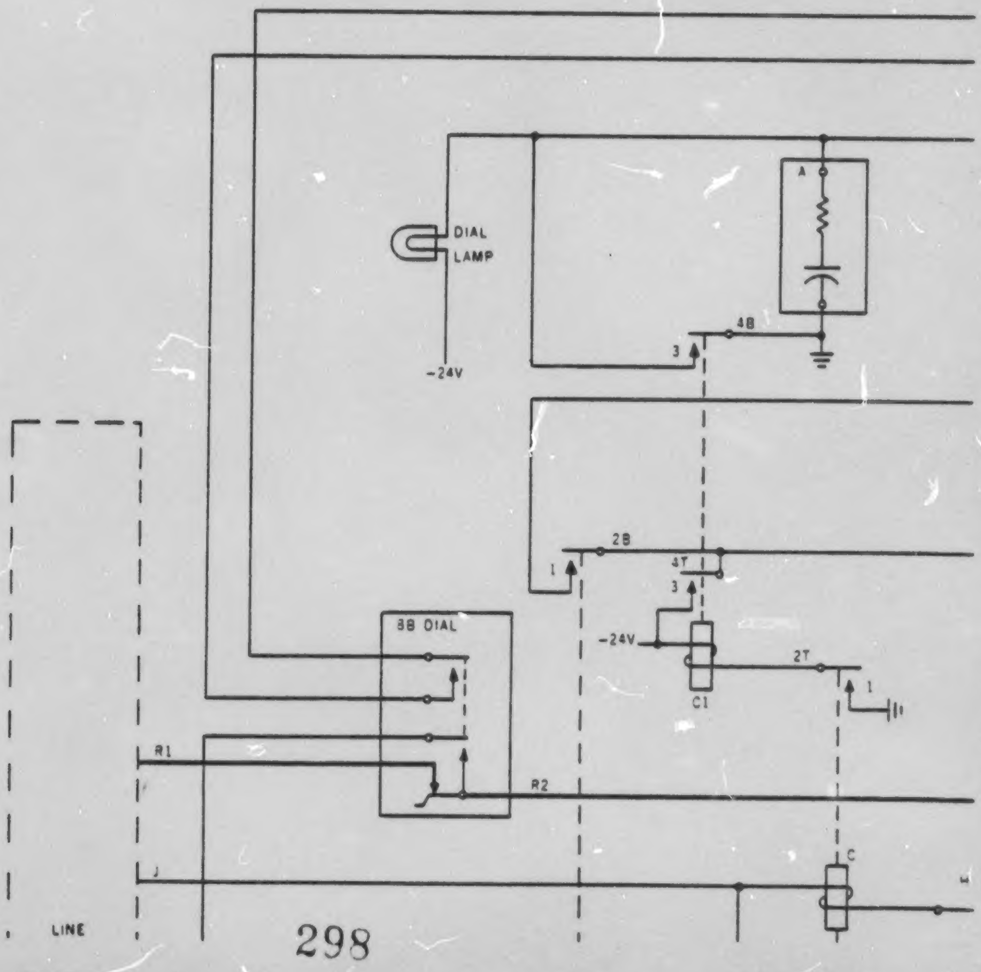
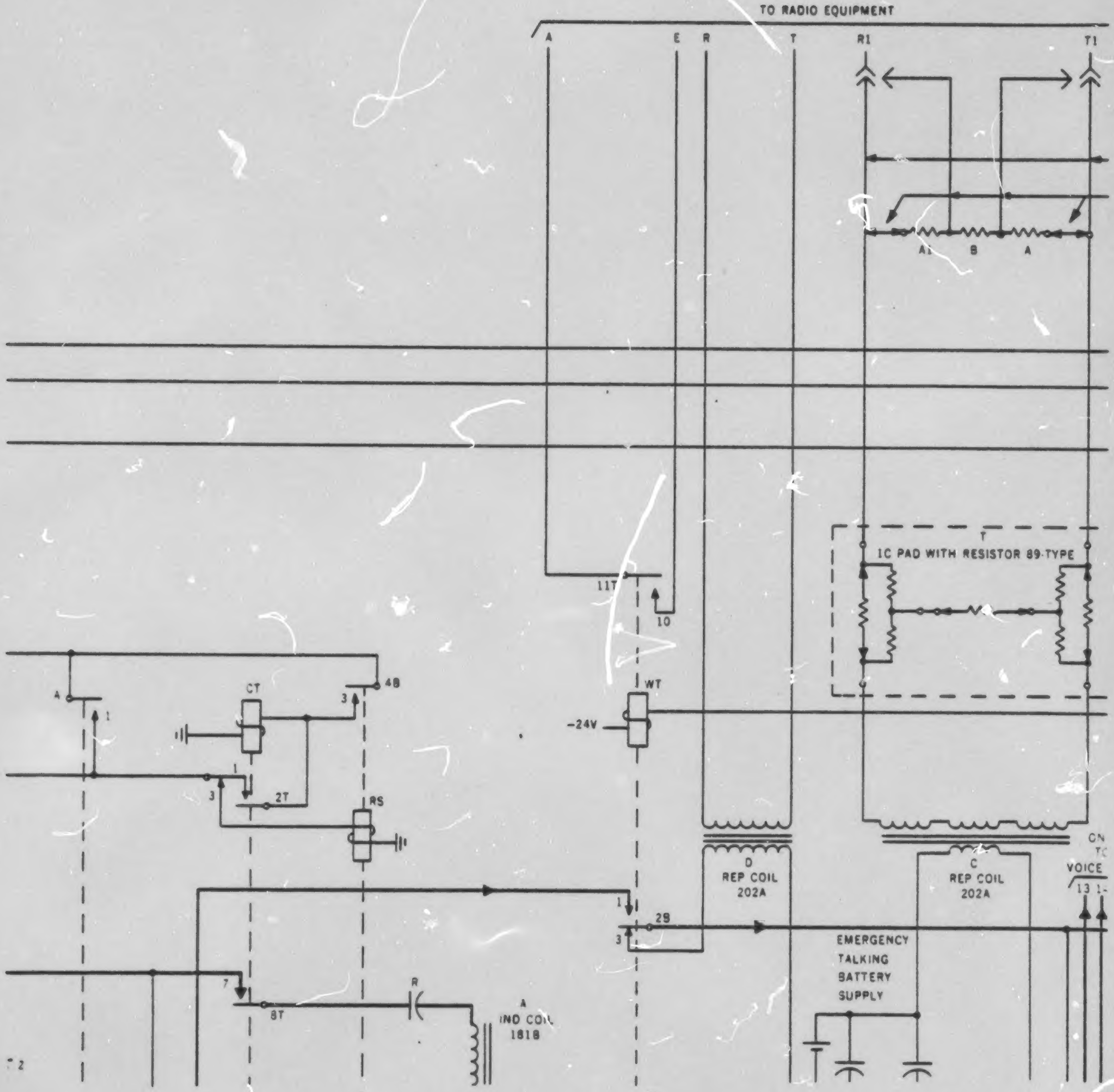
ASSEMBLY OF FOLDOUT 7:

Foldout 7 consists of 6 pages (pages 287 to 292) which should be arranged in the following manner:

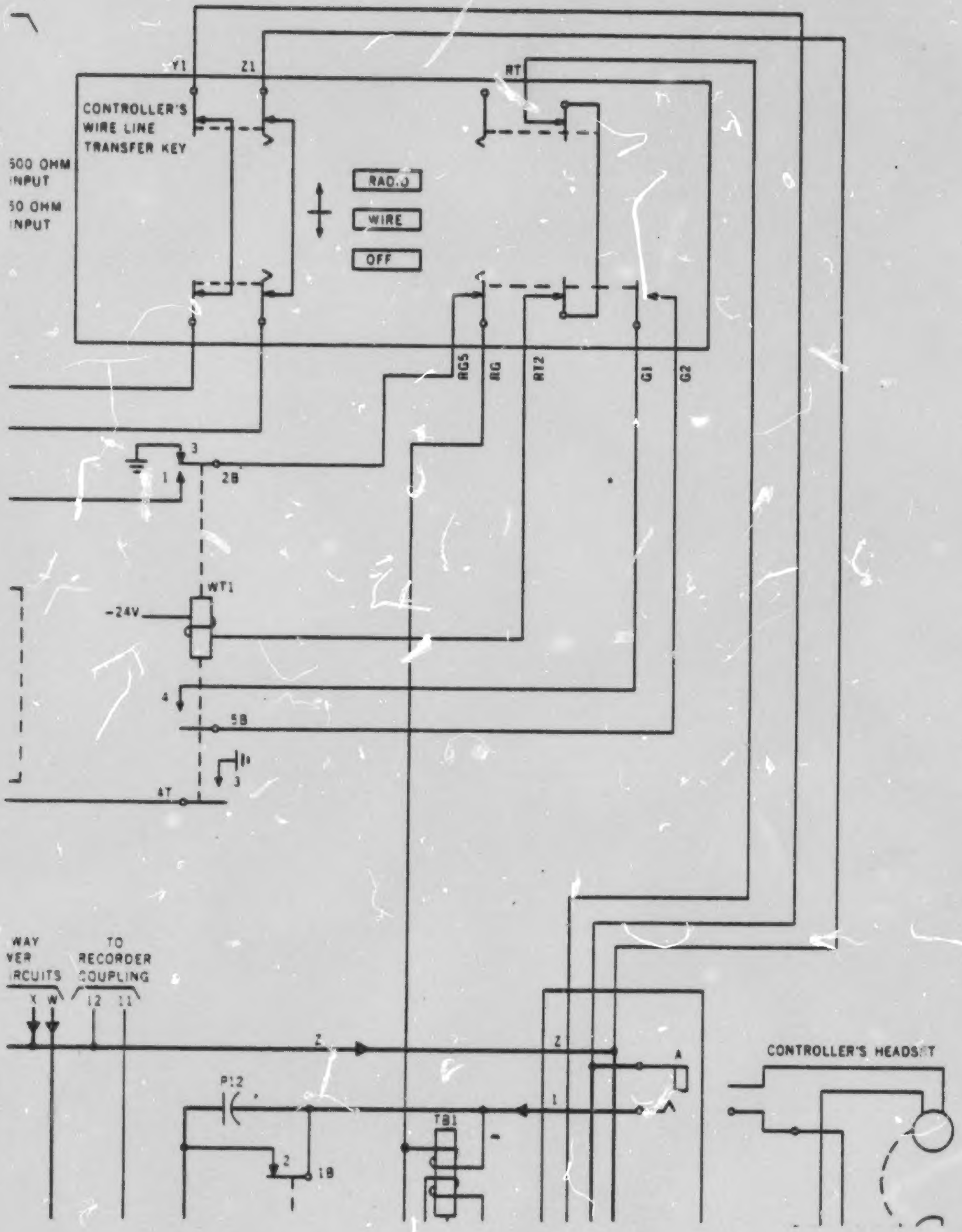
287	288	289
290	291	292


DIAL
LAMP
-24V
A
4B
3
2B
1
4T
3
-24V
C1
2T
1
3B DIAL
R1
R2
J
C
H
LINE

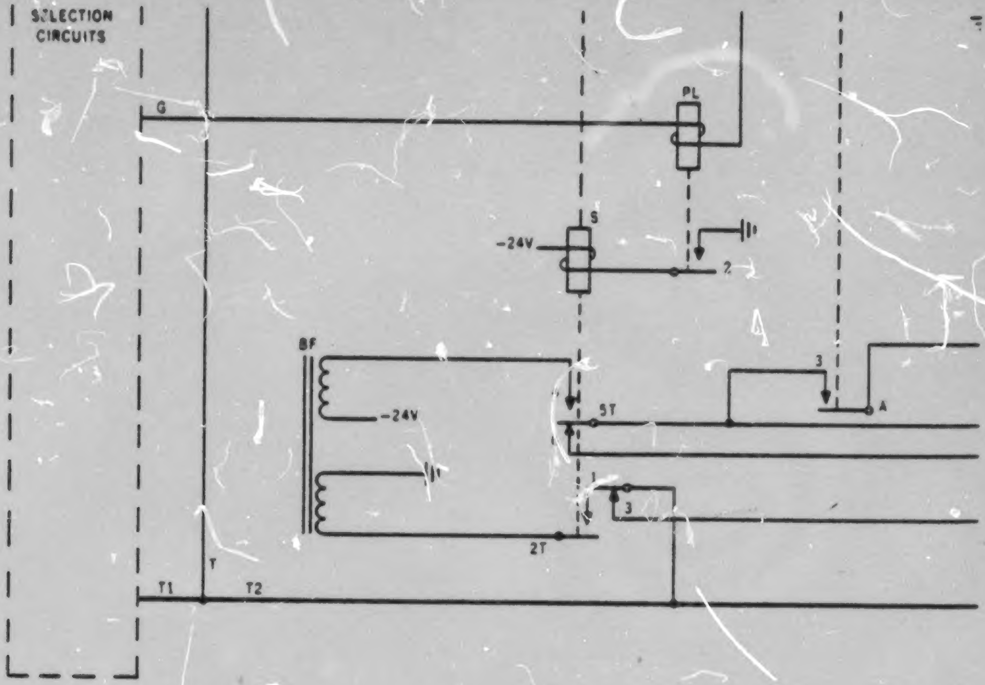
Foldout 7 continued


TO RADIO EQUIPMENT
A
E
R
T
R1
T1
A1
B
A
T
1C PAD WITH RESISTOR 89-TYPE
11T
10
A
1
CT
4B
3
1
3
2T
RS
WT
-24V
D
REP COIL
202A
C
REP COIL
202A
VOICE
13
1
29
3
EMERGENCY
TALKING
BATTERY
SUPPLY
7
8T
R
A
IND COIL
1818

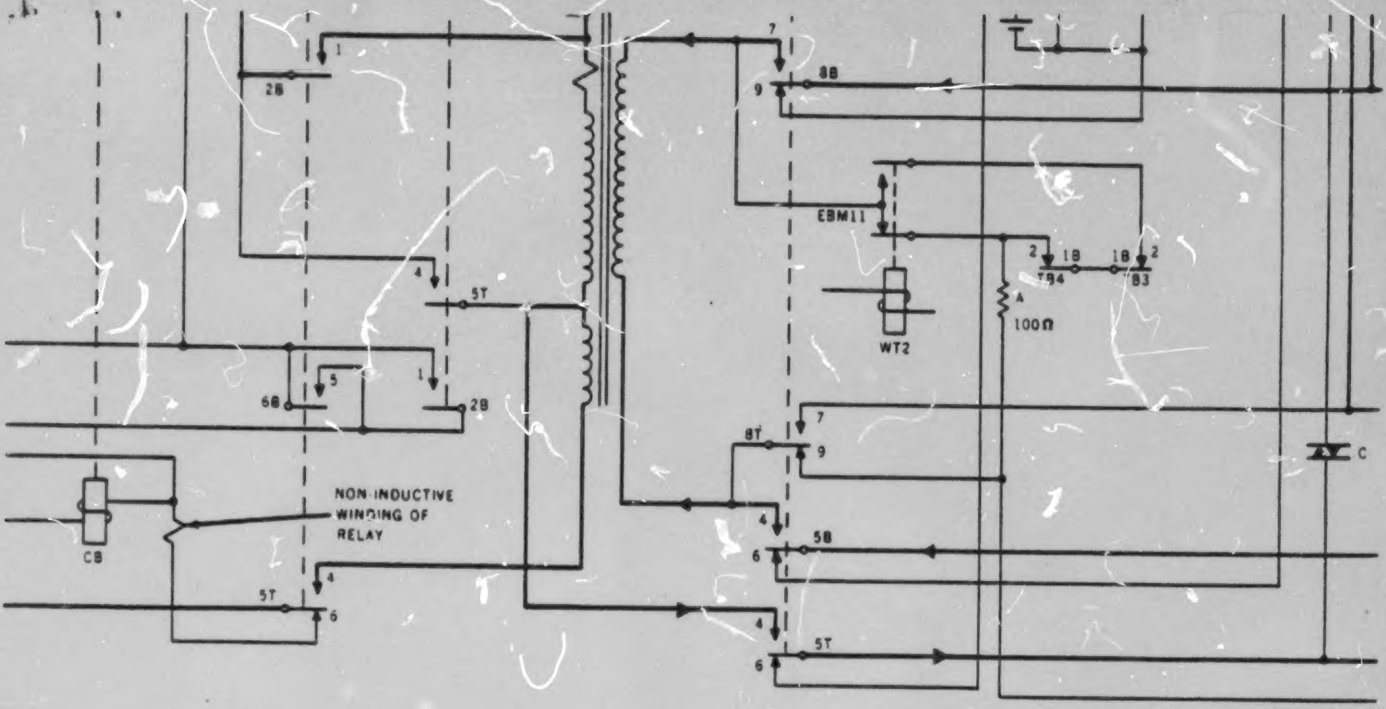
Foldout 7 continued


Y1
Z1
RT
CONTROLLER'S WIRE LINE TRANSFER KEY
500 OHM INPUT
50 OHM INPUT
RADIO
WIRE
OFF
RG5
RG
RT2
G1
G2
3
1
2B
WT1
-24V
4
5B
3
4T
WAY
VER
RCUITS
TO RECORDER COUPLING
X
W
12
11
Z
P12
2
1B
TB1
Z
1
A
CONTROLLER'S HEADSET

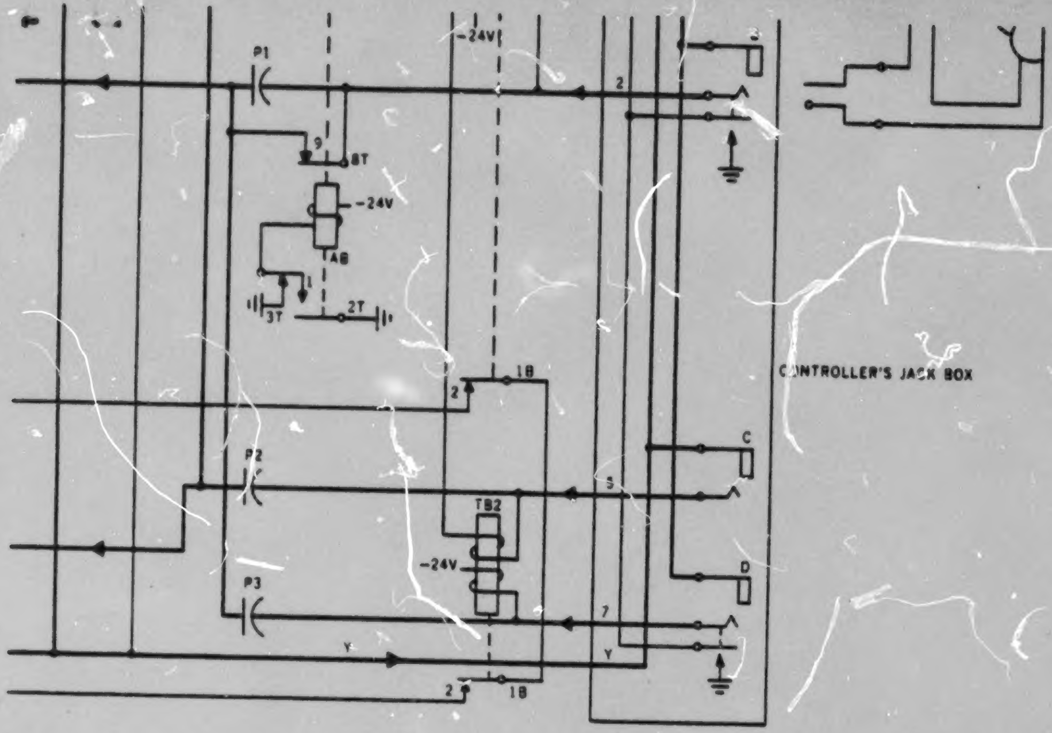
290


SELECTION CIRCUITS
G
PL
S
-24V
2
BF
-24V
3
ST
A
3
2T
T
T1
T2

Foldout 7 continued


2B
1
4
5T
6B
5
1
2B
NON-INDUCTIVE WINDING OF RELAY
CB
5T
4
6
7
8B
9
EBM11
2
1B
TB4
1B
2
TB3
A
100Ω
WT2
7
8T
9
4
5B
6
4
5T
6
C

Foldout 7. Schematic diagram for controller's radio and wire-line termination equipment.


P1
-24V
2
9
8T
-24V
AB
1
3T
2T
B
1B
2
CONTROLLER'S JACK BOX
C
P2
5
TB2
-24V
D
P3
7
Y
Y
2
1B

Foldout 7 continued

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36254 01 22

WORKBOOK

INTRODUCTION TO THE CAREER FIELD

SELF-TEACHING AIDS
CRE
VRE
SRG

This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet.

EXTENSION COURSE INSTITUTE
Air University

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Study Reference Guide

Chapter Review Exercises

Answers for Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume. Use the Guide for review before you take the closed-book Course Examination.

2. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the items missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number

105 Electrical Transmission Security, pages 18-21

106 Introduction to Fundamentals of Electronics; Electron Theory of Matter; Electrical Terms and Electrical Symbols Review; Electrical Diagrams, pages 22-25

107 Voltage, Resistance, and Current Relationship in Electrical Circuits, pages 25-30

Guide Number

108 Voltage, Resistance, and Current Relationship in Electrical Circuits: Resistive Bridge Circuit Analysis, pages 30-33

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CHAPTER 4

Objectives: To demonstrate a knowledge of electrical fundamentals, including electrical terms and symbols, voltage, resistance, and current relationship in electrical circuits; and electromagnetic effects in circuits; and to apply this knowledge in trouble analysis.

1. State a basic law for electricity. (9-1)

2. According to the electron theory, in which direction does current flow? (9-2)

3. What telephone equipment unit produces voltage by a chemical action? (9-3)

4. List three telephone system units which are effective because of current flowing in conductors. (9-3)

5. What illustrating device does a manufacturer use when developing schematic diagrams of his telephone equipment circuits? (10-1)

6. Name the relay which won't operate when current is in both windings. (10-3)

7. Name the term used to describe the action of relay contacts 3 and 4T of relay B in figure 4. (10-5)

8. What voltage should you find at terminal 26 of the terminal strip (see text fig. 4)? (10-8, 9)

9. Identify the two devices connected between terminals A and C within the dashed line block of text figure 4. (10-8, 9)

10. Using text figure 4, name the devices that provide the operating circuit for relay FL1. (11-2)

11. How would you show the condition of contacts 5 and 6T of relay ST on a line and contact drawing (see text fig. 4) if relay A has operated for the second time (X or vertical line)? (11-5)

12. Consider relay FL1 of text figure 4 as having a resistance of 600 ohms. What current would be in the relay when the circuit is complete? (12-2)

13. Identify devices in text figure 7 that limit the current from the battery. (12-5)

14. Assuming that the current in each rectifier of text figure 7 equals 80 milliamperes, what is the total current in the high-voltage secondary of transformer T1? (12-5)

15. Assume that 0.001 ampere of current is in the R4 resistor of figure 7. What is the voltage drop at this resistor? (12-6)

16. What three factors are required to develop voltage? (12-9)

17. What is required for a generator to develop direct current? (12-10)

18. How does the voltage of the primary in figure 7 compare with the voltage in the secondary? (12-7, 11)

19. How does an increase in signal frequency affect the opposition of a wire coil? (12-12)

20. Replacing a 50-millihenry coil with a 30-millihenry coil will have what effect in an ac circuit? (12-13)

21. $X_L = X_C$ when an ac circuit is ________________________________. (12-15)

22. What is the total opposition in the circuit of figure 11? (12-17)

23. Will the current in C_2 of text figure 24 be maximum at the resonant frequency? Why? (12-17)

24. Using text figure 7, is the turns ratio between the primary of T_1 and the high-voltage secondary 1:4 or 4:1? (12-18)

25. What causes an electrical fuse to blow? (12-19)

26. Using the applied voltage and the listed current for text figure 10, what is the total opposition? (12-20)

27. What is the difference in potential between C_4 and C_6 in figure 7? (12-21)

28. What mathematical method will you use to determine current for a series connected component in a series-parallel circuit? (12-22)

29. What is the resistance for a parallel circuit consisting of four resistors having values of 100, 40, 25, and 8 ohms? (12-23)

30. What device reflects a balanced condition in a bridge-type test set? (12-25)

31. Identify the ratio for the four resistors:

R_1 = 1000 ohms
R_2 = 10,000 ohms
(12-26, 27)

R_3 = 500 ohms
R_4 = 5000 ohms

32. Use the resistance values R = 100 ohms, R_2 = 50 ohms, R_3 = 150 ohms, and R_4 = 75 ohms for figure 13 and determine the potential at points A and B. (12-28-30)

33. Use the resistors R_1 = 12 ohms and R_3 = 36 ohms with the circuit of figure 16. What is the resistance for the parallel circuit containing these two resistors? (12-34)

34. How is the balanced bridge reflected by a bridge-type test set? (12-37)

35. A PN junction should normally be connected to the power source in what manner? (12-40)

36. How will battery be connected to a PN junction to obtain forward bias? (12-40; Fig. 19)

37. What particular characteristic makes the PN junction an excellent rectifying device? (12-41)

38. What type electronic circuit requires that a junction diode be connected for reverse bias? (12-42)

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39. Assume that the current of resistor R_1 in figure 21 has increased. Following the increase, what effect would you observe on a voltmeter connected in parallel to the load? (12-42)

40. What is the purpose of a Zener diode circuit? (12-42)

41. With respect to the Zener diode voltage regulator of text figure 21, when the output voltage decreases, will the voltage drop across R_1 be smaller or greater? Why? (12-42)

42. How may you change a transistor's performance? (12-45)

43. Assume that the bias battery is rated at 9 volts and the incoming signal equals 0.2 volts. What is the voltage range that controls the transistor's operation? (12-45, 47)

44. What connecting procedure changes an NPN transistor to a PNP transistor? (12-48)

45. In the circuit of text figure 23, assume that the input signal to the base of the transistor has gone negative. Thus, what change would you find at resistor R_3? (12-48, 49)

46. Which of the three amplifiers (common-base, emitter, collector) produces an output waveform 180° out of phase with the input? (12-49)

47. With respect to transistor amplifiers (common-base, emitter, collector), what potential is at the base? (12-48-50; Figs. 22, 23, 24)

48. Name the amplifier that operates continuously. (12-52)

49. What happens to a thermistor when current flows through it? (12-52)

50. Assume that the battery for the circuit of figure 25 is 9 volts. What, then, is the base-emitter bias voltage for the transistor? (12-6, 52)

51. List some methods by which you provide efficient service to telephone users. (13-1)

52. Would the current for R_2 in text figure 25 increase or decrease following a short-circuit on resistor R_1? (13-2)

53. Identify a probable cause for lamp DS1 in the circuit of text figure 7 not illuminating following operation of switch S_1. (13-3)

54. Assuming that the fuse in text figure 7 has opened, identify the probable cause for this condition. (13-2, 5)

55. Name two circuit conditions which indicate that there has been excessive current in a circuit. (13-5)

56. How do the following statements apply to you? (13-8)

    a. Switch off the power before working with the equipment.
    b. Use insulating matting on the floor when working on high-voltage equipment.
    c. Do not work alone on or near high-voltage equipment. Have a helper stand by where he can see you and where he can reach the main switch hurriedly, in case of an emergency.
    d. Use tools which have rubber insulation.
    e. Remove jewelry before working on this equipment.

57. List sequential procedures which may be used by a telephone equipment repairman. (13-9)

CHAPTER 5

Objective: To be able to show familiarization with the basic fundamentals of telephony, including sound generation and transmission, sound-powered telephony, local-battery telephony, and common-battery telephone principles.

1. How are sound waves carried from their source of generation to the human ear? (14-1)

2. How would you describe the method by which a vibrating body trnasmits its motion to the surrounding atmosphere? (14-2)

3. When a vibrating body sets the surrounding atmospheric particles in motion, creating a sound wave, how far do the particles travel with the wave? (14-3, 4)

4. If you were watching an airplane and it exploded in flight, would you see the explosion before you heard the sound? Why? (14-4)

5. If the sound wave of a steady tone is represented graphically, the waveform on the graph would be of what shape? (14-5)

6. Assuming that two space ships are 100 feet apart and in an environment that is void of any atmosphere, could sound waves be used between the ships for communications? Why? (14-7)

7. How did Alexander Graham Bell's telephone change sound waves into electrical waves? (14-9)

8. Explain briefly the fundamental principle involved in transmitting sound from one point to another by telephony. (14-10, 11)

9. Explain briefly the operation of a sound-powered telephone transmitter. (15-1-6)

10. From the standpoint of being either ac or dc electricity, how would you classify the output of a sound-powered transmitter? (15-3-6; Fig. 34)

11. Give a brief explanation of how the sound-powered receiver operates. (15-8; Fig. 35)

12. During voice transmission on the sound-powered telephone illustrated in figure 36, what is the path of the transmitter current from the transmitter to the distant telephone? (15-10-12)

13. During voice transmission on the sound-powered telephone illustrated in figure 36, what is the circuit path for sidetone? (15-13)

14. What is the circuit path used for voice reception in the sound-powered telephone illustrated in text figure 36? (15-14, 15)

15. On a telephone such as illustrated in figure 36, why is it that the buzzer and visual indicator circuit don't short out the incoming voice signal? (15-14, 15)

16. What is the approximate frequency of the ringing current used with the sound-powered telephone illustrated in figure 36? (15-16, 17)

17. What one feature would identify a telephone system as being of the local-battery type? (16-2)

18. Compare noise and speech sound waves. (16-3, 4; Fig. 39)

19. Explain briefly how the transmitter in a local-battery telephone changes sound waves into electrical waves. (16-6, 7)

20. With respect to electrical classification (ac, dc, etc.,) how is the output of the transmitter on a local-battery telephone classified? (16-7)

21. When the early local-battery telephone consisted of a receiver, battery, and transmitter connected in series, why was the reception poor at the distant receiver? (16-9)

22. What advantages were gained by the addition of an induction coil to the early local-battery telephone? (16-10)

23. In what type of telephone would you be most likely to find a hand generator used for signaling? (16-13)

24. The hand generator used in the local-battery telephone produces what kind of electricity? (16-14)

25. Explain the signaling circuit if party A wishes to call party B as illustrated in figure 44 of the text. (16-14)

26. In a basic local-battery system, what are the main functions of the hookswitch? (16-15)

27. What is meant by the term "sidetone"? (16-18)

28. Why is too much sidetone in a telephone undesirable? (16-20)

29. Why would it be undesirable to remove all sidetone from a telephone set? (16-20)

30. Explain briefly how antisidetone circuit principles are applied to reduce sidetone. (16-21-25)

31. Why is it that modern telephones use induction coils with more than two windings? (16-26)

32. In a circuit such as illustrated in figure 46, what is the reason why sidetone is reduced? (16-26)

33. A simple telephone system of two telephone sets would require how many line pairs? (16-28)

34. In the line signal circuit illustrated in figure 47, what type of current is applied to the winding of I201 when a signal is received from the calling party's telephone? (16-29)

35. Identify local-battery equipment for which you will be responsible. (16-29)

36. Why can two local-battery telephones be considered a complete system? (16-30)

37. What is the main difference between local-battery and common-battery telephone systems? (17-1)

38. From a standpoint of classification, common-battery telephone systems may be subdivided into what basic systems? (17-2)

39. In the common-battery telephone circuit, illustrated in figure 48, what basic circuits are represented? (17-4)

40. In the common-battery telephone circuit, illustrated in figure 48, what telephone part or component serves to connect and disconnect the primary circuit from the central office battery? (17-5)

41. In the common-battery telephone circuit, shown in text figure 48, what is the main purpose of capacitor C (connected in the ringer circuit)? (17-7)

42. In common-battery telephony, how is the central office signaled from a telephone subset? (17-8, 9)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 4

1. A basic law for electricity states that like charges repel and unlike charges attract.

2. According to the electron theory, current flows from the negative terminal to the positive terminal.

3. The battery for a telephone system produces voltage by a chemical action.

4. Telephone system relays, lamps, and alarms operate because of electron flow in conductors.

5. A telephone equipment manufacturer uses electrical symbols to develop schematic diagrams for the equipment of his telephone system.

6. A differential relay in a telephone system does not operate when current is in both windings.

7. "Preparing a circuit" is the term used to describe the action of relay contacts 3 and 4T of relay B in figure 4.

8. Approximately 24 volts dc should be noted at terminal 26 of the terminal strip.

9. Between terminals A and C are connected a fixed resistor and a capacitor.

10. Included in the operating circuit for relay FL1 are a ground, the terminal for contact 4T of relay A, contacts 1T and 2 of relay A, contacts 4T and 3 of relay B, the relay windings of FL1, and battery.

11. A second operation of relay A is provided when relay ST operates. Therefore, contacts 5 and 6T would then be shown beside an X.

12. Using I = E/R (24v/600), relay FL1 would have .040 amperes or 40 milliamperes when its circuit is complete.

13. Resistors R1 and R2 limit the current flowing from the battery.

14. Since the rectifiers are in parallel, their current is added. Hence, 160 milliamperes is the current in the high-voltage secondary of transformer T1.

15. E = I × R = 0.001 × 10,000. E = 10 volts.

16. A magnetic field, a looped conductor, and motion are required for generating voltage.

17. The three factors listed in the answer to question 16 also are necessary for generating direct current. The method of removing the current from the generator output determines the type current in the circuit load.

18. The input voltage to the primary is 117 volts ac, whereas the secondary voltage is 400 volts ac. Since the inducing magnetic field develops an opposing voltage, the secondary and primary voltages are positive and negative at different periods.

19. An increase in ac frequency in a circuit containing a coil increases the opposition of the coil to the circuit.

20. Replacing a 50-millihenry coil with a 30-millihenry coil reduces the opposition for an ac circuit.

21. $X_L = X_C$ when an ac circuit is resonant.

22. The total opposition in the parallel circuit of text figure 11 is 200 ohms.

23. No. Current in a parallel-resonant circuit is minimum because the circuit opposition is maximum (high).

24. Since the voltage in the high-voltage secondary of T_1 is greater than the primary voltage, the turns ratio must be 1:4.

25. A sudden reduction in a circuit's resistance increases the current, thus causing a fuse to blow in an electrical circuit.

26. R = E/I, R = 100/4 amperes, R =25 ohms.

27. Since the voltage at C_4 is 225 volts and the potential at C_6 is 210 volts, the potential difference is 15 volts.

28. Current for a series component in a series-parallel circuit is determined by using Ohm's law (I = E/R). Accordingly, you must first know the voltage at the component and the resistance of the unit.

29. 5 ohms.

30. A galvanometer reflects the balanced condition in a bridge-type test set.

31. $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ or $\frac{1000}{10{,}000} = \frac{500}{5000} = \frac{1}{10}$

    Also $\frac{R_1}{R_3} = \frac{R_2}{R_4}$ or $\frac{1000}{500} = \frac{10{,}000}{5{,}000} = \frac{2}{1}$

32. Branch 1 total resistance of 150 ohms causes 0.12 ampere for the branch. Hence the voltage drop for R_1 is 12 volts. The 225 ohms resistance of branch 2 permits 0.080 ampere in the branch. Voltage drop at R3, then, is likewise 12 volts. Points A and B are therefore 12 volts negative with respect to the positive side of the battery.

33. Parallel resistors having 12 and 36 ohms provide a circuit resistance of 9 ohms.

34. A balanced bridge circuit allows no current to be in the galvanometer of a bridge-type test set.

35. A PN junction should normally be connected with the P-type material attached to a positive potential and the N-type material to negative. Following this connection, current will be at its maximum value.

36. Positive battery will be connected to the P side of the junction and negative battery will be connected to the N side for forward bias.

37. The ability to conduct in one direction makes the PN junction an excellent rectifier.

38. A junction diode is connected for reverse bias in the voltage regulator circuit.

39. Following an increase in current within this resistor, there will be a temporary change in voltage across the load because the current also flows in CR_1 which is in parallel with the load. Remember, too, that branch voltages are the same.

40. The purpose of a voltage regulator is to keep the output of a power supply constant.

41. The voltage drop will be smaller because the current through the diode will be reduced. Less current through the diode causes less voltage drop across R_1.

42. To change a transistor's performance you change the bias.

43. A transistor having a bias voltage of 9 volts and a signal voltage of 0.2 is, in turn, controlled by a voltage that ranges from 8.8 volts to 9.2 volts.

44. By reversing the battery connections, you change a NPN transistor to a PNP transistor.

45. A negative signal to the base of the transistor in figure 23 would reduce the collector current. A decrease in current for a fixed resistor (R_3), in turn, reduces the voltage drop.

46. The common-emitter amplifier produces an output waveform 180° out of phase with the input.

47. A positive potential is at the base of the common-base, emitter, and collector amplifiers.

48. A class A amplifier operates continuously.

49. Resistance of thermistor is reduced following the introduction of current because of the heat generated.

50. A 9-volt battery for the class A amplifier of figure 25 provides approximately 1.6 millaimperes of current for resistor R_1. Ohm's law shows that the bias voltage for the transistor is E= .0016 X 600 ohms. Thus, E = .96 volts.

51. The manner in which you perform is indicative of good service. Good performance results when you think clearly and use a logical sequence of troubleshooting steps to locate troubles.

52. Following a short-circuit, current in an electrical circuit must increase because the resistance is decreased.

53. No current in the circuit keeps a lamp dark and no current is to be found in an open circuit.

54. Any large increase in current will blow the fuse protecting the equipment.

55. Blackened devices and burned odors indicate that a circuit has had excessive current.

56. Since these are safety rules for repairmen of electronic circuits, you must likewise consider them when preparing to work with telephone equipment.

57. Look for symptoms of trouble, inspect the equipment, analyze the circuits, and test to isolate the fault.

CHAPTER 5

1. Sound waves are carried from their source of origination to the human ear by a medium such as the air or atmosphere.

2. A vibrating body causes first a bunching up of the surrounding atmospheric particles and then a thinning out or rare-faction of the atmospheric particles. Thus, it creates sound waves in the atmosphere.

3. The atmospheric particles do not actually travel along with the wave. Rather, they collide with their outer neighbors, impart their energy, and then return to a point close to their original position. The outer neighbors likewise collide with neighbors and transfer energy.

4. You would see the explosion before you heard the sound, because sound waves travel more slowly than light waves. The light waves are the medium by which you see the explosion.

5. The sound wave of a steady tone would be uniform in shape.

6. No. Sound waves will not travel in a space that is void of atmosphere.

7. Bell's telephone used an arrangement in which sound waves caused a relative motion between a coil of wire and a magnetic field. Thus, a voltage was induced in the coil that matched the shape of the sound waves.

8. To transmit sound by telephone, the sound waves are first converted to electrical waves by a unit called the transmitter; the electrical waves are then transmitted over wires to their destination. The receiver converts the electrical waves back into sound waves.

9. Sound waves striking the diaphragm in a sound-powered transmitter move an armature positioned within a coil of wire and between the poles of a permanent magnet. This movement induces electrical current in the coil; thus, current is developed for the telephone line.

10. The output of a sound-powered transmitter is ac electricity.

11. In operation, the electrical waves generated by the transmitter cause waves of current in the coil winding of the receiver. These waves of electric current produce a magnetic field that causes the receiver diaphragm to vibrate. This diaphragm vibration reproduces the sound waves.

12. During voice transmission, switch S1 would be in the talk position; hence, transmitter current would flow through the switch and line L2 to the receiver of the distant telephone. It would return over L1 and the hand generator switch to the other side of the transmitter.

13. The circuit path for sidetone in figure 36 is from the lower terminal of the transmitter, through the talk contact of switch S1, resistor R1, receiver RE1, capacitor C1, and back to the other side of the transmitter.

14. The circuit path for voice reception in figure 36 is from terminal L1, through the normally closed contacts of the generator switch, capacitor C1, receiver RE1, and through the listen contact of switch S1 to terminal L2.

15. The buzzer and visual indicator don't short out the incoming voice signals because their impedance value is quite high for the voice frequencies.

16. The ringing frequency is approximately 20 cycles per second.

17. A local-battery system has a battery in each telephone.

18. Noise sound waves are very irregular, whereas speech sound waves are more uniform.

19. The transmitter used with the local-battery telephone varies its resistance in accordance with the sound waves striking its diaphragm. Therefore, it varies the current in the circuit, producing a waveshape similar to the sound waves.

20. The output of a local-battery transmitter is classified as variable dc.

21. The line resistance was too high with respect to the amount of resistance change in the transmitter; therefore, the signal was weak at the distant receiver.

22. The induction coil allowed the transmitter circuit to be shortened and, of course, the transformer action of the induction coil then provided a stronger signal for transmission.

23. The hand generator is used in the local-battery telephone.

24. The hand generator produces an alternating current.

25. In text figure 44, the generator switch for telephone A is in the position it assumes while the generator is being operated. With the switch in this position, the ringing circuit is completed to the ringer of telephone B via lines L1 and L2 and the unoperated generator switch is telephone B.

26. The lifted hookswitch completes the transmission circuit. The restored hookswitch opens the transmission path and connects the ringer to the line.

27. Sidetone refers to the signal that reaches the receiver from the transmitter of the same telephone. For example, when you hear your own voice in a telephone receiver as you talk into its transmitter, you are then hearing sidetone.

28. Too much sidetone in a telephone will cause the user to lower his voice, thus reducing the signal to the distant telephone. Also, a telephone located in a noisy area provides sidetone noise in the receiver that will interfere with reception from the distant telephone.

29. If the telephone user cannot hear his voice in the telephone receiver, as would be the case if all of the sidetone were removed, he would shout and talk too loud when using the telephone.

30. In antisidetone circuitry, the principles of circuit balance are applied to reduce the sidetone. With this type of circuitry there is a voltage cancelling action which reduces the sidetone for the receiver for all voice frequencies.

31. Additional windings are used on induction coils to provide for better sidetone control.

32. In the circuit shown in text figure 46, the potential is balanced across the receiver. That is, at the instant represented by the illustration, the potential applied to both sides of the receiver is negative.

33. A simple telephone system of two telephone sets would require one line pair.

34. Because of the diode illustrated for this circuit, the current applied to the winding of I201 is pulsating direct current.

35. You will be responsible for line terminals, line drops, line protectors, and subset components such as battery, network, ringer, hookswitch, dial, and cords.

36. Local battery telephones are complete systems because they have their own sources of electrical energy for transmission and signaling.

37. Basically, the main difference between local-battery and common-battery telepho[illegible]tem is in the way electrical power is supplied. In local-battery systems, the electrical power is supplied locally at each telephone, whereas in common-battery systems, the electrical power is supplied at the central office for the entire system.

38. Common-battery telephone systems may be divided into two categories: manual and automatic (dial) systems.

39. Three basic circuits are represented by the illustration of text figure 48: the primary circuit (transmitter), the secondary circuit (receiver), and the ringing circuit.

40. The hookswitch connects and disconnects the primary circuit from the central office battery.

41. Capacitor C is placed in the ringer circuit to keep the ringer from being a constant drain on the central office battery.

42. When the receiver is removed from its cradle on a common-battery telephone, the hookswitch completes a circuit all the way to the central office battery. With the manual system, this completed circuit to the central office lights a lamp on the switchboard to signal the operator. With the dial system, a circuit operates a line relay that connects the calling telephone to the switching equipment.

STOP– **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 PENCIL.** 3/2

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VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

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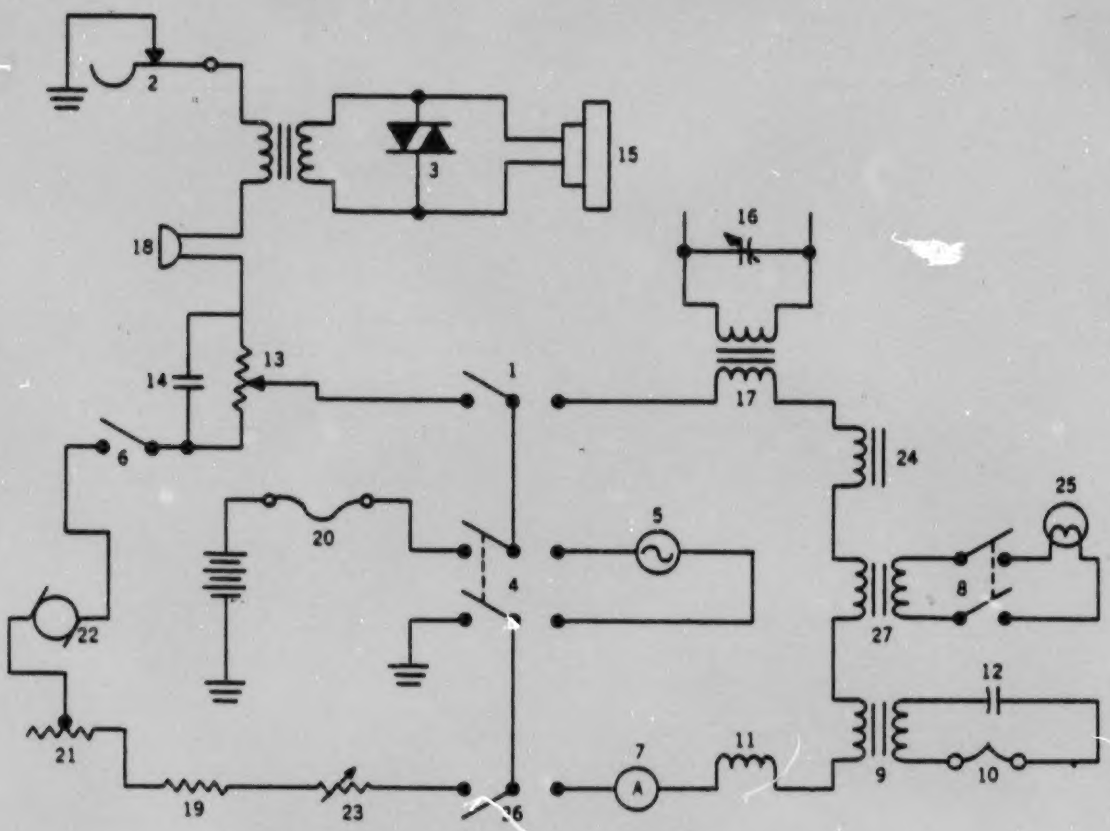
3/3 *Note to Student.* For questions 33, 34, 35, and 36 refer to VRE figure 1.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Volume Review Exercise Figure 1 for Questions 33, 34, 35, and 36.

33. (023) Which of the numbered symbols is for a DPST switch?

a. Number 1.
b. Number 4.
c. Number 6.
d. Number 8.

34. (023) Which of the numbered symbols is for the hookswitch?

a. Number 2.
b. Number 6.
c. Number 22.
d. Number 26.

35. (023) Which of the numbered symbols is for a rheostat?

a. Number 11.
b. Number 13.
c. Number 19.
d. Number 21.

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36. (023) Which of the numbered symbols is for a variable capacitor?

a. Number 3.
b. Number 12.
c. Number 14.
d. Number 16.

37. (026) When two 10-ohm resistors are connected in parallel with a 24-volt battery, the total current flow in the circuit is

a. 5 amperes.
b. 4.8 amperes.
c. 2.4 amperes.
d. 1.2 amperes.

38. (026) The total current in a parallel circuit is

a. less than the current through any of the branches.
b. equal to the sum of the currents through all of the branches.
c. equal to the source voltage divided by the sum of the resistance values.
d. equal to the source voltage divided by the value of the smallest branch resistance.

39. (027) A dc generator does which of the following?

a. Uses sliprings to connect the armature to the external circuit.
b. Reverses current flow periodically in the external circuit.
c. Produces alternating current in the armature.
d. Doubles input power with sine wave output.

40. (027) Alternating current is produced by

a. transforming rectifiers.
b. bridge-type rectification.
c. moving a magnetic field into coiled conductors.
d. rotating resistors at 60 revolutions per second in phase.

41. (027) The output of a generator may be increased by all of the following methods *except*

a. moving the conductors with greater speed parallel to the lines of force.
b. increasing the speed of relative movement between the magnetic field and conductors.
c. increasing the strength of the magnetic field.
d. forming the moving conductor into a coil.

42. (028) A coil in an ac circuit has a

a. frequency which will not vary.
b. farad opposition.
c. farad of reactance.
d. back EMF.

43. (028) The process by which current in one loop of the primary winding induces voltage in loops of a secondary winding is called

a. self-induction.
b. mutual reactance.
c. mutual induction.
d. conductive reactance.

315

44. (028-029) Which of the following would you expect to find in a resonant ac series circuit?

a. Maximum current.
b. Maximum opposition.
c. Minimum current.
d. Zero voltage at the reactor.

45. (029) A parallel resonant circuit provides

a. minimum impedance for the passage of its harmonic frequencies.
b. maximum impedance for the passage of nonresonant frequencies.
c. minimum impedance for the passage of its resonant frequency.
d. maximum impedance for the passage of its resonant frequency.

46. (029) Current developed by magnetic flux transfer in transformers is

a. dc only.
b. ac only.
c. measured in microfarads.
d. symbolized with two long lines between the transformer primary and secondaries.

47. (029) Applying the resonant frequency to a series connected inductor and capacitor causes

a. this frequency to be blocked.
b. current in the circuit to be minimum.
c. impedance in the circuit to be reduced.
d. impedance in the circuit to become higher.

48. (030) When placing a milliammeter in an electronic circuit, you should install it so that

a. the meter parallels the power source.
b. the meter resistance does not affect the power source output.
c. most of the current passes through the circuit component being shunted by the meter.
d. current through the meter is the same as that which passes through the circuit components.

49. (030) Which of the following statements is correct concerning a parallel circuit?

a. Voltage across each component is the same.
b. Current through each of the components is the same.
c. Resistance of each of the components is the same.
d. Total resistance is the sum of the component values.

50. (033) What circuit condition results when you provide reverse bias to a PN junction?

a. Battery current withdrawal is increased.
b. Power source is shut off automatically.
c. Battery current withdrawal is decreased.
d. Power source voltage is decreased.

51. (034-036) Which of the following circuits is the most acceptable transistor amplifier?

a. Common-emitter.
b. Common-base.
c. Common-collector.
d. Grounded base.

52. (034) A signal which is larger at the output of a transistor than it was at the input has

a. been amplified.
b. observable distortion.
c. little value in electronic equipment.
d. a small potential across the load resistor.

53. (034) When a PNP transistor is used as an amplifier, a positive-going input signal should

a. reverse the battery bias.
b. overcome the battery bias.
c. stabilize the battery bias.
d. be observable at the output.

54. (036) Which amplifier conducts without interruption so that its output signal is linear?

a. Class AB.
b. Class A.
c. Class B.
d. Class C.

55. (037) A circuit fuse opens because the circuit resistance has

a. decreased, causing a decrease in current.
b. increased, causing a decrease in current.
c. decreased, causing an increase in current.
d. increased, causing an increase in current.

56. (037) When noise is a symptom of circuit trouble, you should inspect the

a. fuse and ON lamp.
b. inductor and capacitor.
c. discriminator and ON-OFF switch.
d. thermistor and resonant transformer.

57. (037) Infinite opposition is in an electronic circuit when

a. a capacitor is tested.
b. a resistor is short-circuited.
c. a capacitor is short-circuited.
d. a series-connected device is open.

58. (040) The sound wave for a steady tone is represented graphically by a waveform that is

a. similar to the one used to illustrate a distorted amplified signal.
b. similar to the one used for pure dc.
c. uniform in shape.
d. uneven in shape.

59. (040) A vibrating body or object produces sound waves by

a. moving membranes at db levels in the outer ear.
b. thinning and rarefying receiver carbon granules.
c. compressing and bunching surrounding granules of air.
d. compressing and rarefying groups of atmospheric particles.

60. (041) In which of the following is it impossible for sound waves to travel?

a. Vacuum.
b. Solid metal.
c. Body of water.
d. Tank of pure air.

61. (041-042) The early telephone produced by Alexander Graham Bell converted sound waves to electrical waves by

    a. varying the dc of a battery.
    b. varying the resistance in the transmitter.
    c. inducing voltage in a coil within the telephone.
    d. applying an ac current to a coil in the telephone receiver.

62. (042) The early Bell telephone converted electrical waves to sound waves by

    a. varying the dc current applied to the telephone receiver.
    b. applying dc speech waves to a coil in the telephone receiver.
    c. varying the resistance of a coil in the telephone receiver.
    d. applying ac electrical waves to a coil in the telephone receiver.

63. (043) In sound-powered telephony, the electrical power used for voice transmission is

    a. furnished by a hand generator.
    b. generated by the telephone transmitter.
    c. generated by the telephone induction coil.
    d. furnished by a dry-cell battery in each telephone set.

64. (044) When a sound-powered receiver is receiving the electrical waves produced by a sound-powered transmitter, the receiver armature is operated by

    a. electromagnetic attraction.
    b. electromechanical polarization.
    c. a connecting rod attached to the receiver diaphragm.
    d. a push-rod which extends from the receiver diaphragm to the armature.

65. (044-045) During transmittal with the telephone set illustrated in figure 36 of the text, resistor R1

    a. limits the sidetone through the receiver element.
    b. limits the direct current through the receiver element.
    c. reduces the voice frequency current applied to terminal L1.
    d. reduces the battery current through the primary and transmitter circuits.

66. (045) When incoming voice signals are received with the telephone illustrated in figure 36 of the text, the signal passes through the telephone from L1 to L2 by which one of the following paths?

    a. Through the generator switch contacts, capacitor C1, receiver RE1, and resistor R1.
    b. Through the generator switch contacts, transmitter MK1, and the talk contacts of switch S1.
    c. Through the generator switch contacts, capacitor C1, receiver RE1, and listen contacts of switch S1.
    d. Through the generator switch contacts, capacitor C1, receiver RE1, and the talk contacts of switch S1.

67. (045) If the generator switch were switched to the opposite position from the position shown in figure 36 of the text, the telephone would then be in position for

    a. receiving voice signals.
    b. sending ringing signals.
    c. receiving ringing signals.
    d. transmitting voice signals.

68. (045) In local-battery telephones, the electrical energy used in voice transmission is supplied by

a. the telephone transmitter.
b. a battery at the central office.
c. a battery in each telephone set.
d. a generator in each telephone set.

69. (046) The transmitter on a local-battery telephone changes sound waves into electrical waves by

a. inducing a voltage in the transmitting circuit.
b. varying the resistance in the transmitting circuit.
c. generating alternating current in the transmitter circuit.
d. varying the source voltage applied to the transmitter circuit.

70. (046) The wave produced by the carbon transmitter is

a. pure direct current.
b. variable direct current.
c. pure alternating current.
d. variable alternating current.

71. (047) The addition of a two-winding induction coil to the early local-battery telephone

a. provided the required circuitry for moving the battery to the switchboard.
b. permitted the use of a battery in the secondary circuit.
c. increased the transmitting power of the telephone.
d. decreased the telephone line resistance.

72. (048) Placing the receiver on its hookswitch

a. disconnects the hand generator from the line circuit.
b. disconnects the telephone ringer from the line circuit.
c. connects the transmitter, battery, and receiver to the line circuit.
d. disconnects the transmitter, battery, and receiver from the line circuit.

73. (049) When the sidetone circuitry of a telephone is functioning properly, you should

a. be able to hear your voice in your own telephone receiver.
b. not be able to hear your voice in your own telephone receiver.
c. not be able to hear background noise in your telephone receiver.
d. be able to hear only the voice of the party at the other telephone.

74. (048) With local-battery telephones, the ringing current is normally of what frequency?

a. 15 cycles per second.
b. 20 cycles per second.
c. 60 cycles per second.
d. 108 cycles per second.

75. (048) When the hand generator of a local-battery telephone is operated, the output of the generator armature is connected to the line circuit by

a. a hand-operated switch on the ringer.
b. a hand-operated switch on the telephone housing.
c. an automatically operated switch on the hand generator.
d. an automatically operated switch on the telephone housing.

76. (048) The telephone circuit shown in figure 44 of the text allows telephone A to signal telephone B. Which of the following changes to the circuit would allow telephone B to signal telephone A?

a. Change the generator switch in telephone B to its opposite position.
b. Change the generator switch in telephone A to its opposite position.
c. Change the generator switches in both telephones to their opposite positions.
d. Change the generator switch in telephone A to the same position as the switch in telephone B.

77. (049) If a circuit such as is shown in figure 45(d) of the text balances out the sidetone effect of the sound entering the transmitter, it receives sound from the distant telephone because the

a. circuit is unbalanced for signals entering at terminals L1 and L2.
b. circuit is balanced for signals entering at terminals L1 and L2.
c. potential is equal between points A and B for signals entering the circuit at terminals L1 and L2.
d. signal from the distant telephone is amplified to the point where is overcomes the antisidetone effect.

78. (049) If the ratio of impedance Z1/Z2 is equal to the ratio of impedance Z3/Z4 in the circuit shown in view B of figure 45, the

a. difference in potential across the receiver is unbalanced.
b. current through the receiver is of medium value.
c. circuit is unbalanced.
d. circuit is balanced.

79. (050) In the circuit shown in figure 46 of the text, sidetone through the receiver is held to a minimum because

a. there is no voltage induced in the lower induction coil winding.
b. the voltage in the upper induction coil winding cancels the voltage in the lower coil.
c. the current in the center winding of the induction coil is opposite from that in the primary.
d. the voltages applied to both sides of the receiver are of equal but opposite polarity.

80. (051) In figure 47 of the text, the current that passes through the winding of I201 is

a. pure dc.
b. pure ac.
c. pulsating dc.
d. pulsating ac.

81. (051-052) In a common-battery telephone system, the electrical power required for operation is supplied by

a. the central office.
b. batteries in each telephone.
c. batteries at the central office and in each telephone.
d. electrical power plants located at various points in the system.

82. (052) The primary circuit of the common-battery system illustrated in figure 48 of the text consists of the

a. transmitter, capacitor, and the primary winding of the induction coil.
b. transmitter, ringer, and the primary winding of the induction coil.
c. transmitter, hookswitch, and the primary winding of the induction coil.
d. transmitter, hookswitch, and the secondary winding of the induction coil.

83. (052) Most of our modern telephone systems are of which type?

a. Manual local-battery.
b. Manual common-battery.
c. Automatic local-battery.
d. Automatic common-battery.

84. (052-053) In the telephone circuit shown in figure 48 of the text, capacitor C

a. functions as a part of the antisidetone circuit.
b. functions as a part of the transmitting circuit.
c. blocks dc from passing through the ringer.
d. blocks ac from passing through the ringer.

85. (053) With a manual common-battery system, the telephone user signals the switchboard operator by

a. using his hand generator.
b. lifting the receiver from its cradle.
c. dialing zero on most telephone subsets.
d. lifting the receiver and using the hand generator.

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2. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the items missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

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CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that test. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To demonstrate an understanding of the equipment and components used as station equipment in the common-battery telephone system. To operate common-battery telephone circuits and use telephone diagrams.

1. Which telephone components are normally housed by the modern telephone handset? (1-1, *a*)

2. What is the main purpose of the telephone handset cord? (1-1, *b*)

3. Assuming that a common-battery telephone does not contain a network assembly, which major components would be housed in the telephone housing? (1-1, *c*)

4. On an ordinary telephone installation, where is the mounting cord used? (1-1, *d*)

5. Name four major components of the modern telephone set. (1-1)

6. How is the resistance of a transmitter varied by sound waves? (1-4, 5)

7. What is the primary difference between the old solid back transmitter and the carbon cup transmitter? (1-6, 7)

8. When the transmitter unit of a modern telephone becomes defective, how is it repaired? (1-9)

9. What does it mean if it is said that a transmitter has noise-canceling characteristics? (1-10)

10. Why is the permanent magnet important to receiver operation? (1-13-15)

11. How is the permanent magnet arranged in the modern telephone receiver? (1-17)

12. What are the main functions of the telephone induction coil? (1-18)

13. What are the main functions of the capacitors used in telephones? (1-20)

14. What is the main difference between local-battery telephony and common-battery telephony? (2-1)

15. What is a telephone exchange? (2-4)

16. Name the major components of a local-battery telephone. (2-5)

17. Why is it that local-battery telephones will function in a system that does not have a central office? (2-6)

18. Why is it necessary to have a central office when common-battery telephones are used? (2-7, 8)

19. With common-battery telephones, how is the switchboard operator signaled from a telephone substation? (2-9)

20. In comparison with the local-battery system, what are some of the advantages of the common-battery telephone system? (2-12, 13)

21. With a three-winding induction coil, such as shown in figure 10, what names are commonly used for the windings? (3-2)

22. With the telephone circuit illustrated in figure 10 of the text, the hookswitch contacts would be placed in what position when the handset is placed on its cradle? (3-2)

23. In the circuit illustrated in figure 10 of the text, which one of the induction coil windings is connected into the circuit in a direction that is opposite from the other two windings? (3-3; Fig. 10)

24. In a circuit such as illustrated in figure 10, which component would be considered as the heart of the antisidetone circuit? (3-4)

CHAPTER 2

Objectives: To show knowledge of how to install and repair equipment used in automatic (dial) telephone systems. To trace the dial (common-battery) telephone circuit. To demonstrate an understanding of the circuitry and operation of the 500-type telephone, and the general construction of explosionproof and weatherproof sets.

1. What are the main differences between the manual common-battery system and the dial common-battery system? (4-1)

2. How is the switchboard battery connected to the subscriber's telephone in the manual common-battery system? (4-1)

3. Name four basic types of electromechanical dial telephone systems. (4-3)

4. During dialing with an automatic telephone system, how are the dial pulses established on the telephone line? (4-5)

5. What information does the dial tone convey to the calling party? (4-6)

6. How are telephones connected automatically by the dial system? (4-6, 7)

7. With a simplified dial system, such as illustrated in figure 12 of the text, the dialing of the number 68 into the connector switch would move its wiper to what position? (4-7)

8. What is the main difference between the XY and step-by-step dial systems? (4-8)

9. If a telephone subscriber dialed the number 54 into the stepping switch of an XY telephone system, the switch wipers would step to what position? (4-9)

10. What is the purpose of the pulse spring contacts used in the telephone dial? (5-2)

11. How many times do the dial pulse springs open and close (break and make contact) when the digit 0 is dialed? (5-2)

12. As illustrated by figure 13 of the text, which telephone circuit is interrupted by the dial pulse springs? (5-2)

13. Why is the receiver circuit disabled during the dialing of each digit? (5-3)

14. As illustrated by figure 13 of the text, which telephone circuits are affected by the closing of the dial shunt spring contacts? (5-3)

15. As shown in part B of figure 13 of the text, the 0.7-mf capacitor serves what purpose? (5-4)

16. As shown in figure 13D of the text, the main transmitter circuit from terminal L2 to terminal L1 is through which telephone components? (5-5)

17. What tones are connected by the telephone line by a touch-tone telephone following depression of pushbutton 5? (6-2)

18. What subscriber actions operates telephone switching equipment? (6-4, 5)

19. Does a telephone call which extends through step-by-step equipment and between rotary dial subscribers require signal conversion? (6-6, 7)

20. Identify the equipment to be inspected if signal conversion fails to occur. (6-8)

21. With a simplified dial and switch circuit, such as shown in figure 15 of the text, what happens when the subscriber removes the handset from the cradle of his telephone? (7-2)

22. With a simplified dial and switch circuit, as illustrated in figure 15 of the text, what happens in the circuit when the subscriber dials a given digit? (7-3, 4)

23. Explain briefly how the telephone dial operates. (7-4, 5)

24. As a telephone equipment installer-repairman, name a dial system control device for which you will be responsible. (8-1)

25. Name the device which serves as a guide for the subscriber preparing to dial a desired number. (8-4)

26. Why is a finger stop on the telephone dial? (8-5)

27. What is the purpose of the pulse cam used with the telephone dial? (8-7)

28. What is the purpose of the shunt spring assembly used in the telephone dial? (8-9)

29. What is the purpose of the shunt cam assembly used in the telephone dial? (8-9, 10)

30. How is the pulsing rate at which the line circuit is pulsed controlled? (8-14)

31. Why must the telephone dial operate at the proper speed? (8-14)

32. What is the proper dial speed for the majority of telephone systems? (8-14)

33. How is the speed of a telephone dial normally checked? (8-15)

34. During the dialing sequence, when do the shunt springs return to their normal position? (8-9, 16)

35. Which pair of spring contacts perform in approximately the same manner in all telephone dials? (8-17)

36. In the dialing circuit shown in figure 17 of the text, what function is performed by the contacts between dial springs 5 and 6? (8-18)

37. In the dialing circuit shown in figure 17 of the text, what is accomplished during dialing by the closing of the contacts between dial springs 3 and 4? (8-18)

38. In the circuit illustrated in figure 17 of the text, the contacts between dial springs 1 and 2 will open and close how many times when the digit 4 is dialed? (8-18)

39. What telephone is most widely used throughout the Air Force? (9-1)

40. Which of the commercial 500-type telephones used by the Air Force have parts that are interchangeable? (9-2)

41. From the standpoint of appearance, what is the main difference in the looks of the dial on the 500 telephone as compared with the early model dial? (9-3)

42. What is the difference between the handset cord used with the 500 telephone and the handset cord used with the older model telephone? (9-4)

43. Name seven basic components that must be used in a dial common-battery telephone to provide satisfactory service. (9-5)

44. In comparison with the units used in older telephones, how has the transmitter unit in the 500 telephone been improved? (9-6)

45. How are the handset cord conductors connected to the transmitter unit in the handset used with the 500 telephone? (9-7)

46. In addition to serving as a mounting for the transmitter, the plastic cup used in the handset of the 500 telephone performs what other important functions? (9-7)

47. What is the purpose of the varistor that is connected across the terminals of the receiver in the handset of the 500 telephone? (9-8)

48. How are the handset conductors connected to the receiver unit in the handset used with the 500 telephone? (9-8)

49. What is the purpose of contacts F and G on the hookswitch used with the 500 telephone? (9-10)

50. On the 500 telephone, what is the position of hookswitch contacts B-C and D-E when the handset is removed from its cradle? (9-11)

51. In respect to construction, what is the main difference between the coils used on the 500 telephone ringer and the ones used on older telephones? (9-12)

52. Which parts are replaceable on the 500 telephone ringer? (9-13)

53. What spring contacts are provided on the dial used on the 500 telephone? (9-14)

54. What is the purpose of the off-normal contacts used on the 500 telephone dial? (9-14)

55. Explain briefly which parts of the 500 telephone are contained in the network assembly. (9-16, 17)

56. How is the 500 telephone normally repaired when a network part becomes defective? (9-18)

57. Name the principal circuits of the 500 telephone. (9-20)

58. In reference to figure 26 of the text, the primary induction coil winding located between network terminals RR and R is identified by which letter-number combination? (9-20)

59. In reference to figure 26 of the text, which two induction coil windings, in conjunction with resistor R2, form a series circuit between network terminals RR and GN? (9-20)

60. As illustrated by figure 26 of the text, which side of the central office battery is connected through to terminal L2 on the network? (9-21)

61. What is usually meant by a ground symbol on a telephone wiring diagram? (9-22)

62. During the installation of telephone wiring at the connecting block, what practice is normally followed by installer-repairmen to help in the identification of the tip and ring sides of the line? (9-23)

63. As connected in the circuit illustrated in figure 26, what is the purpose of the yellow mounting cord conductor that is connected between the tip terminal of the connecting block and the G terminal on the network? (9-24, 25)

64. Why should the handset be on its cradle when the 500 telephone is receiving ringing current from the central office? (9-25)

65. What type of ringing current is normally supplied from the central office? (9-26)

66. Assuming that a specific half-cycle of ringing current leaves the central office via the tip conductor, passes through the circuitry shown in figure 27, and then returns to the central office via the ring conductor, which direction will this current pass through the slate-red ringer lead in the illustration? (9-26)

67. Removing the handset from its cradle on the telephone circuit illustrated in figure 26 will place the hookswitch contacts in what position? (9-27)

68. With the tip and ring conductors in figure 28 connected to central office battery and the handset removed from its cradle, how would the current flow in the induction coil windings between terminals RR and C? (9-28)

69. When someone speaks into the transmitter of a telephone such as illustrated by the circuit in figure 28, the induced voice currents from the induction coil appear across which terminals of the network? (9-30)

70. The equalizer circuitry of the network (fig. 28) consists of which parallel circuits? (9-30)

71. Use figure 28 to determine the induction coil windings and the network terminals used when voice currents are received by a 500 telephone. (9-30, 31)

72. When receiving with the 500 telephone (fig. 26), the induced currents that flow in the receiver are induced in which winding of the induction coil? (9-31, 32)

73. During receiving with the 500 telephone (fig. 26), the induced current that flows through the receiver from network terminal GN to network terminal R returns to the induction coil winding via which circuit paths? (9-32)

74. What is meant by the term antisidetone? (9-34)

75. Name two ways in which the network assembly functions during a normal telephone conversation. (9-34)

76. Why is it that the voice currents received by the 500 telephone induce a strong voltage in induction coil winding S1? (9-35)

77. In figure 28 of the text, the transmitter and resistor R1 are connected into a series circuit. What other components of the network form a series circuit that is connected in parallel with the transmitter and resistor R1? (9-36)

78. How does the circuitry shown in figure 28 reduce sidetone during transmission? (9-36)

79. In respect to the 500 telephone, the dialing current passes through the network components via what circuit paths? See figure 28. (9-38)

80. In the network assembly of the 500 telephone, in figure 28, what is the purpose of capacitor C2? (9-38)

81. In reference to the 500 telephone, explain how the off-normal contacts of the dial short out the receiver. (9-38)

82. Name some other types of telephones that use the same type of network circuitry as that used in the 500 telephone. (10-1)

83. Explain briefly how telephones are constructed to make them explosionproof. (10-2)

CHAPTER 3

Objectives: To show knowledge of the functions of maintenance and maintenance management and inspection systems, and to show a knowledge of related documentation.

1. What should result from having management centralized? (11-1)

2. Most maintenance performed at workcenter Y6720 is ______________ level maintenance. (11-1, 2)

3. Replacing a 400B KTU for the 1A2 key system would most likely be what level of maintenance? (11-2)

4. What level of maintenance is used when modifying a 212A for emergency use? (11-3)

5. Where should you send a telephone system component that needs to be calibrated or restructured? (11-4)

6. At the organizational level, who directs the maintenance programs? (12-1)

7. List responsibilities of the chief of maintenance. (12-2)

8. Name an effective method by which the chief of maintenance will manage maintenance for his organization. (12-3, 4)

9. Identify the maintenance directives from the chief of maintenance. (12-4)

10. Use text figure 30 and name the staff positions for the chief of maintenance. (12-5)

11. List four duties for the production analysis section at the CEM. (12-6)

12. Identify considerations for training management when preparing a training program. (12-7)

13. Name the inspections for which quality control is responsible. (12-10)

14. Give procedures to use when a repairman is suspected of performing maintenance poorly. (12-11)

15. Name the chief of maintenance office to whom you would submit a request for Bell Telephone Specifications. (12-12)

16. Identify the method you will use to correct observed deficiencies. (12-13)

17. To whom do you report when requesting additional KTUs for your organizations? (12-14)

18. List fundamental factors for planning and scheduling maintenance. (12-16)

19. What type maintenance would replacement of a wire clamp be? (12-17)

20. Identify the publications to use when documenting maintenance. (12-18)

21. Name the materiel control function that orders 400B-type KTUs and monitors to see that the order will arrive as scheduled. (12-19)

22. What procedure does management use to identify problem areas of maintenance and forecast requirements? (13-1)

23. Of what system is the AFTO Form 349 a part? (13-2)

24. Describe a way in which good maintenance management improves the organization. (13-1-3)

25. How did the Air Force simplify maintenance documentation for the technician? (13-3-5)

26. Using text figure 32 as your guide, determine a job control number for the tenth job for June 20, 1972. (13-6)

27. Identify the letter that you will use on maintenance forms to designate that the maintenance being performed is on 302 system equipment. (13-8)

28. From what document would you get the number 4640 shown in column K of the sample maintenance form? (13-10)

29. If you spent 2 hours inspecting and testing 10 relays in a key system, how many minutes did you average per relay? (13-11)

30. What type maintenance form entry do you make to indicate the type work you have done to 302 system equipment? (13-12)

31. Having corrected a trouble during routine maintenance, where do you get the entry to place in block E of the Maintenance Data Collection Record form? (13-12)

32. Why must you use the correct codes when completing a Maintenance Data Collection Record form? (13-14)

33. Using text figure 33 determine the man-hours used to find and correct all loose connections in the 500-type telephones. (13-15)

34. What is the most necessary control required for producing an efficient maintenance organization? (14-1)

35. Identify the code to use when you have spent a half-hour washing and polishing the shop vehicle. (14-3)

36. Who checks each master roster and identifies the errors, if there are any? (14-4)

37. How does the exception card relate to good management? (14-5)

38. What circumstance permits a workcenter to have more man-hours to its account at the end of a reporting period than when the period began? (14-6)

39. Name the entries you will make on a man-hour accounting card. (14-4, 6, 8)

40. How are airmen helped by maintenance records? (15-1)

41. What document is your authority to install a telephone for a customer? (15-2, 3)

42. Compare the telephone set installation work order with the key system record/worksheet. (15-3, 4)

CHAPTER 4

Objectives: To show knowledge of how to maintain and inspect telephone sets, to detect and control corrosion, and to use telephone test sets, click sets, and multimeters. To locate faults—repair telephone sets—using test equipment to test telephone circuits and components, and to correct troubles in telephone parts and assemblies.

1. Name two categories into which general telephone maintenance may be divided. (Intro.-2)

2. Why are preventive maintenance inspections performed on subset installations? (16-1)

3. What items of associated equipment should you inspect when looking for troubles at a subset installation? (16-1)

4. If you were looking for troubles at a subset installation, what would you look for while inspecting the drop wiring? (16-1, *b*)

5. Why should the carbon blocks in a station protector be in good condition? (16-1, *c*)

6. What one thing, more than anything else, is largely responsible for the formation of corrosion? (16-3)

7. While inspecting the terminals, wiring, protectors, etc., at a subset installation, what should you look for to detect corrosion? (16-2-4)

8. How is corrosion normally controlled? (16-6, 7)

9. When you install a telephone subset, what factors should you consider relative to the prevention of corrosion? (16-9)

10. When corrosion is found in a component of a substation installation, what should be done to correct the situation? (16-10)

11. As a supervisor of telephone installation, during what part of a specific installation job would you consider the prevention of corrosion? (16-11)

12. Name four operations of the telephone set to which malfunctions may be isolated. (17-1)

13. What is the first step that you should take when you are troubleshooting in the subset area? (17-2)

14. Why must you follow a series of systematic steps when troubleshooting telephone equipment? (17-4)

15. Why should the troubleshooting procedure be carried through to the final step even though the telephone malfunction is located by one of the first steps made? (17-4)

16. When looking for troubles at a telephone installation, why should you examine and test the associated equipment (terminals, drop wiring, etc.) before you test the internal circuits of the subset? (17-6)

17. If you were troubleshooting in a subset area and it became necessary to use test instruments, at what point in the circuit would you perform the first test? (17-6)

18. If you were troubleshooting in a subset area and you found that the trouble was on the central office side of the pole terminal, what should you do to correct the situation? (17-6)

19. Why should the correction of troubles in the subset area be coordinated with the wire chief or test desk operator? (17-6, 10, 11)

20. Why should the wire chief perform tests before he sends an installer-repairman out to look for troubles in a subset area? (17-11)

21. If you were assigned the job of finding a trouble at a subset installation, how could you do the job systematically? (18-1)

22. How can the installer-repairman use the telephone test set to determine if battery is present on a specific telephone pair? (18-2)

23. How can the installer-repairman use the telephone test set to identify the battery side of the line? (18-2)

24. What response will you note from a click set if you connect it to an open circuit? (18-3)

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25. The battery-powered click set is used to test what type of telephone circuits? (18-4)

26. Explain briefly how a telephone click set is constructed. (18-5)

27. Assuming that the conductors of a telephone pair have been disconnected from central office battery, what is indicated if you hear a loud click when you connect a battery-powered click set between one of the conductors and ground? (18-6)

28. With a multimeter, what method is used to measure different amounts of voltage with the same basic meter movement? (18-9)

29. With a multimeter, what method is used to measure different amounts of current with the same basic meter movement? (18-10)

30. With a multimeter that uses a dc meter movement, what method is normally used to read ac values with the unit? (18-11)

31. Which of the multimeters described in the text provide for the most accurate testing? (18-12)

32. In respect to ohms per volt, what is the sensitivity rating of the TS-297/U multimeter? (18-14)

33. What is the largest voltage range provided on the TS-297/U multimeter? (18-15)

34. On the TS-297/U multimeter, which jack is common to all measurements? (18-15)

35. On the TS-297/U multimeter, what is meant by the label "RX10" located by a resistance jack at the lower part of the meter? (18-15)

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36. While measuring dc milliamperes with the TS-297/U multimeter, which jack must be used as the negative connection to the meter? (18-15)

37. What is the purpose of the rheostat located just below the meter on the TS-297/U multimeter? (18-16)

38. Name the three basic scales used on the face of the TS-297/U multimeter. (18-17)

39. To interpret readings on the various scales of the TS-297/U multimeter, how would you determine which scale to read? (18-18)

40. If you were using the TS-297/U multimeter to measure an ac voltage of about 200 volts and you wanted the meter pointer to deflect to approximately half-scale, which meter jack would you use, where would you set the selector switch, and what meter scale would you read? (18-19)

41. If you are measuring a dc voltage with the TS-297/U multimeter and the red test lead is plugged into the 400V jack, the selector switch is set in the DCV-MA position and the pointer on the meter is pointing to the number 20 on the 0 to 40 DC scale, what voltage reading is being indicated? (18-19)

42. If you are measuring a dc voltage with the TS-297/U multimeter and the red test lead is plugged into the 10V jack, the selector switch is set in the DCV-MA position, and the pointer on the meter is pointing to the number 25 on the 0- to 100-DC scale, what voltage reading is being indicated? (18-19)

43. When preparing to make a resistance measurement with the TS-297/U multimeter, how would you set the meter to zero? (18-21)

44. When you measure the resistance in a circuit with a multimeter, why should you disconnect the circuit from its power source? (18-21)

45. If you are making a resistance measurement with the TS-297/U multimeter and the red lead is plugged into the RX 10 jack, the selector switch is set in the OHMS position, and the pointer on the meter is pointing to the number 30 on the OHMS scale, how much resistance is indicated? (18-22)

342 46. If you wanted to measure a resistance value of about 200 ohms with the TS-297/U multimeter and you wanted the pointer on the meter to deflect to approximately half-scale, which resistance jack should you use? (18-22)

47. In respect to the PSM-6 multimeter, how much current is required to make the meter movement read full scale? (18-23)

48. In respect to ohms per volt, what sensitivity ranges are provided by the PSM-6 multimeter? (18-23)

49. Explain the purpose of the control switches and rheostat used on the PSM-6 multimeter. (18-24-27)

50. What is the maximum resistance that may be indicated by the PSM-6 multimeter? (18-29)

51. If you are measuring dc voltage with the PSM-6 multimeter and the range switch is set at the 250 position, which scale should you read on the meter? (18-29)

52. If you are measuring dc voltage with the PSM-6 multimeter and the function switch is set at the DCV (20K per volt) position, the RANGE switch is set at the .5 position, and the pointer on the meter is pointing to the position identified by the numbers 1.5, 3, and 6 on the DC scale, how much voltage is being indicated? (18-29,30)

53. When using the accessory probe to measure up to 5000 volts dc on the PSM-6 multimeter, which meter scale must be used to obtain the reading? (18-30,31)

54. When using the accessory probe to measure up to 5000 volts dc, the FUNCTION switch on the PSM-6 must be set in what position? (18-30,31)

55. What is the maximum ac voltage that can be measured with the PSM-6 multimeter? (18-33)

56. What is the purpose of the OUTPUT position on the PSM-6 multimeter? (18-34)

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57. Without using the accessory instrument shunt, what is the maximum amount of current that can be measured with the PSM-6 multimeter? (18-35)

58. When you use the accessory instrument shunt to read maximum current with the PSM-6 multimeter, which scale should you read on the meter face? (18-35)

59. If you wanted to measure a resistance of approximately 40 ohms with the PSM-6 multimeter and you wanted the meter pointer to deflect to a position near the lower end of the scale, at what positions should you set the FUNCTION and RANGE switches to make the measurement? (18-37)

60. If the meter pointer points to the number 6 on the DC scale when you are measuring microamperes with the PSM-6 multimeter, how many microamperes are indicated? (18-38)

61. Name some of the general precautions that should be observed when using a multimeter. (18-40)

62. Give the main precautions that should be observed when using a multimeter to measure current values. (18-42)

63. Name the main precautions that should be observed when using the multimeter to measure resistance values. (18-43)

64. If you are troubleshooting in the subset area and you find that the subset is functioning normally except that its bells do not ring when signaled by the central office, what circuits should you examine next? Why? (19-1)

65. When a trouble is believed to be in a telephone set, what checks should you make before you test the internal circuits of the set? (19-3)

66. If you have traced a trouble down to a telephone set, what operational tests should you then perform to help in isolating the malfunction? (19-4)

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67. Assuming that you are troubleshooting an installed telephone, explain briefly how you would perform operational tests on the set. (19-5,6)

68. When localizing a trouble in an installed telephone by monitoring its operation with a telephone test set, to what basic circuits may the trouble be isolated? (19-7)

69. When you check the operation of an installed telephone by monitoring its operation with a test set, what is indicated if you cannot hear dial tone in either the test set or the telephone receiver when the handset is removed from its cradle? (19-8,a)

70. When checking the operation of an installed telephone by monitoring its operation with a test set, what is indicated if you cannot hear dial tone in the receiver of the telephone when the handset is removed from its cradle but you can hear it in the receiver of the test set? (19-8,b)

71. When checking the operation of an installed telephone by monitoring its operation with a test set, what is indicated if you continue to hear dial tone in both the telephone and test set receivers after dialing a number with the telephone? (19-8,c)

72. Explain briefly how you would perform a complete inspection of a telephone handset. (19-11)

73. If you find the ringer biasing spring is broken on a late model telephone, how should the unit be repaired? (19-12,c)

74. Explain briefly what you would look for while inspecting a telephone hookswitch. (19-13)

75. What are some of the main things to look for when inspecting such items as an induction coil or a network assembly? (19-14,15)

76. What are the main points to be checked when inspecting a telephone dial? (19-17)

77. What would you look for while inspecting the handset and mounting cords? (19-18)

78. When you test the resistance of telephone components with a multimeter, why is it necessary to disconnect some of the units during the test? (19-20)

79. When testing the resistance of a telephone component with a multimeter, why should you select a range that will give you a reading on the lower half of the meter scale? (19-20)

80. How would you test the 101A induction coil with a multimeter? (19-21)

81. The specified resistance value for the primary winding of the 101A induction coil is 22 ohms. Would you consider a 101A induction coil to be defective, if its primary winding measured 20 ohms? Why? (19-21)

82. Why is it that a network assembly may still be defective even when all of its resistance values are satisfactory? (19-22)

83. Why should you always lock up the specified values for any telephone component that you may be testing? (19-23)

84. Why is a resistance test of a transmitter not very reliable? (19-25)

85. What checks can be performed on the dial contacts with a multimeter? (19-26)

86. Explain how a ringing or talking capacitor may be checked with a multimeter. (19-27)

87. When you test the receiver and transmitter circuits, as illustrated in figures 44 and 45 of the text, which one of the circuits should be tested first? (19-29)

88. Explain how the telephone transmitter circuit is tested with a telephone test receiver. (19-29-31)

89. When testing the transmitter circuit as illustrated in figure 44 of the text, what is indicated if the test is satisfactory from point A to point B, but it is not satisfactory from point A to point C? (19-30)

90. If you were testing from point A to point B of a transmitter circuit, as shown in figure 44 of the text, what would be indicated if sound did not come through the test receiver? (19-30)

91. When testing a transmitter circuit such as the one shown in figure 44 of the text, what is indicated if the test from point A to point C is satisfactory but sound does not come through the test receiver while testing from point A to point D? (19-31)

92. Explain how the telephone receiver circuit is tested with a telephone test receiver. (19-32-34)

93. When testing a receiver circuit such as the one shown in figure 45 of the text, what is indicated if no click is heard while testing from point A to point B? (19-33)

94. When testing a receiver circuit such as the one shown in figure 45 of the text, what is indicated if no click is heard when the test receiver with its battery is connected directly across the terminals of the handset receiver? (19-34)

95. When the telephone dial is at rest (no number being dialed), its pulsing contacts are in what position? (19-35)

96. The pulse spring contacts in a telephone dial are in what position when the subscriber is talking over his telephone? (19-35)

97. Why is dial speed an important factor in the operation of a dial telephone? (19-36)

98. What dial pulse speed is used with most of the automatic switching systems? (19-36)

99. If a telephone dial is operating at the proper speed, how long should it take for it to return to its normal position when you dial the digit zero? (19-36)

100. When the dial assembly is not functioning properly, what is the best method for correcting the trouble? (19-38)

101. What function of the hookswitch contacts is common to practically all telephones? (19-40)

102. What is the purpose of the shorting contacts used on the hookswitch of some telephones? (19-40)

103. Why is a capacitor connected in series with the ringer on common-battery telephones? (19-42)

104. If the ringer capacitor in a telephone subset shorts out, what is the effect on the telephone system? (19-42)

105. When the ringer is defective on the modern telephone, what is the normal method of repair? (19-43)

106. With the modern telephone, how are such components as the transmitter, receiver, hookswitch, network assembly, and instrument cords usually repaired? (19-45-47)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. The transmitter and receiver are housed by the telephone handset.

2. The handset cord provides a means of connecting the transmitter and receiver in the handset with the components in the telephone housing.

3. The common-battery telephone housing with other than a network assembly would contain the ringer, hookswitch, induction coil, capacitors, and either a dial blank or a dial assembly.

4. The telephone mounting cord is used to connect the circuitry of the telephone housing to the telephone wiring at the connecting block.

5. The four major components which make up the modern telephone set are:

   a. The handset.
   b. The handset cord.
   c. The telephone housing assembly.
   d. The telephone mounting cord.

6. The resistance of a telephone transmitter is varied by changing the pressure applied to its carbon granules. When sound waves strike the transmitter, the diaphragm vibrates, changing the pressure on the carbon granules. Thus, the resistance of the transmitter is varied by the sound waves striking the transmitter diaphragm.

7. The difference between the solid back transmitter and the carbon cup transmitter is in the carbon arrangement. The cup provides a more positive contact between the carbon granules and allows the transmitter to be moved freely while in use. Such movement was not possible with the solid transmitter, because the loose granules jarred enough to create a frying noise.

8. The modern transmitter unit must be replaced when it becomes defective.

9. A transmitter with noise-canceling characteristics will transmit only the sound that is fed directly into it. That is, it will not transmit the sound that is produced either behind or at the sides of the unit. It may also be said that this transmitter has directional characteristics.

10. The permanent magnet is important to receiver operation because it aids the receiver in making a good reproduction of the transmitted sound. Without the permanent magnet, each alternation of receiver current attracts the receiver diaphragm, causing it to produce sound waves that are twice the frequency of the transmitted sound waves.

11. The permanent magnet in the modern receiver is ring-shaped; thus, it concentrates the magnetic lines of force near the receiver diaphragm.

12. The telephone induction coil aids in the reduction of sidetone while transmitting; and it provides for good transmission and reception.

13. Some of the main functions of telephone capacitors are:
    - *a.* To block dc current from passing through components such as the ringer and receiver.
    - *b.* To pass ringing and voice currents as desired.
    - *c.* To aid the induction coil during operation.

14. The main difference between local- and common-battery telephone systems is in how the electrical power is furnished for the system. With local-battery systems, the power is furnished at each telephone set. With common-battery systems, the electrical power is furnished from the central office for all of the telephone sets in the system.

15. The central office with its connected lines and substations is called a telephone exchange.

16. The major components of a local-battery telephone are the receiver, transmitter, battery, induction coil, switch, hand generator, and ringer.

17. With local-battery telephones, the sources of electrical energy for transmitting and signaling are included in each subset. Therefore, local-battery telephones may be used in a system that does not have a central office.

18. Since common-battery telephones are not equipped with the necessary components for generating their own electrical power, they must be connected to a system where the power for signaling and transmission is furnished.

19. The operator is signaled by a lamp which operates automatically when the handset is removed from its cradle at the substation.

20. The chief advantages of a common-battery system are that a centrally located battery is easier and more economical to maintain; the line voltage is more constant, and the user can signal the operator by simply removing the handset from its cradle.

21. The induction coil windings are usually called the primary, secondary, and balancing windings. In many cases, however, the balancing winding may also be called the tertiary winding.

22. Placing the handset on its cradle in the circuit illustrated in figure 10 would open both sets of hookswitch contacts.

23. The secondary winding is connected into the circuit in a direction that is opposite from the other two windings.

24. The induction coil is the heart of the antisidetone circuit.

CHAPTER 2

1. With manual common-battery systems, the switching and connecting of stations is done by operators in the central office. With dial common-battery systems, the switching and connecting of stations is done automatically in the central office; the switching is done by automatic equipment which responds to the subscriber's telephones.

2. In the manual common-battery system, the switchboard battery is supplied when the operator makes a connection for the subscriber.

3. *a.* Step-by-step system.
   b. XY system.
   c. All -relay system.
   d. Crossbar system.

4. During dialing, the dial interrupts the line current by alternately opening and closing the dial pulse contacts.

5. The dial tone indicates to the calling party that the equipment is ready for him to dial the number of his choice.

6. The dial system extends the connection, one step at a time, as each digit of the number is dialed. If the called station is not busy, it is signaled by the application of ringing current through the last switch in the switch-train. When the called party removes his handset from its cradle to answer the call, the final connection between the two telephones is completed.

7. The dialing of the number 68 into the connector switch would first move the wiper up to the 6th row and then around to the 8th terminal in the 6th row.

8. The main difference between the XY and step-by-step dial systems is in the type of stepping switches used.

9. The dialing of the number 54 into an XY stepping switch would first cause it to take 5 steps in the X direction and then 4 steps in the Y direction.

10. The dial pulse contacts (pulse springs) pulse the central office switching equipment during dialing.

11. The dial pulse springs open and close 10 times when the digit 0 is dialed.

12. As shown by this illustration, the telephone circuit from terminal L2 to terminal L1 is interrupted. This, of course, interrupts the line circuit to the central office during dialing.

13. The receiver is disabled during the dialing period to eliminate the clicking noise that would otherwise be present in the receiver.

14. As shown in this illustration, the lower shunt spring shorts out the receiver, and the upper shunt springs short out the transmitter and primary winding of the induction coil.

15. The 0.7-mf capacitor, in conjunction with the 100-ohm resistor, serves as an arc suppressor for the pulse spring contacts.

16. As shown in figure 13D, the main transmitter circuit from terminal L2 to terminal L1 is through the transmitter, the 2-1 winding of the induction coil, the dial pulse contacts, and the hookswitch contacts to terminal L1.

17. Depression of pushbutton 5 results in tones 770 and 1336 cps being connected to the line.

18. Lifting the handset and dialing sends pulses of electric current which operate the telephone equipment, but in association with the dial there must be tones.

19. No. A call between two rotary dial subscribers is connected by telephone switching equipment in the normal manner and requires no signal conversion.

20. When signal conversion fails to occur, the interface equipment should be inspected.

21. When the subscriber removes the handset from the cradle of his telephone, the hookswitch closes, completing a circuit through the dial pulse springs, the telephone lines, and realy A in the central office. This causes relay A to operate and to extend ground to the circuit of relay B. This ground is extended by the action of the contacts which are shown directly below relay A. The extension of ground to relay B causes it to operate, closing the contacts to the magnet circuit. The magnet circuit does not operate at this time, however, because relay A is holding the grounded armature (shown directly below it) in contact with the relay B circuit.

22. To dial a digit or number, the subscriber must first remove the handset from its cradle. Removal of the handset from its cradle places the circuit in a condition as described in the answer to question 21. With the circuit in this condition, the dialing of a digit opens and closes the pulse spring contacts the same number of times as the number of the digit dialed. Each time that the pulse spring contacts open and close, relay A releases and reoperates. As relay A releases, the grounded armature moves downward, extending ground to the magnet circuit; and the reoperation of relay A immediately lifts the grounded armature to reestablish contact with the circuit to relay B. This action pulses the magnets one time, moving the switching equipment one step. Each time that the pulse springs open and close, the magnet circuit operates to step the switching equipment one step. Thus, when a specific digit is dialed, the equipment is pulsed or stepped the same number of times as the number of the digit.

23. To dial a specific digit or number, the subscriber places a finger in the proper hole of the finger plate (finger wheel) and turns it in clockwise direction until his finger touches the finger stop. He then removes his finger from the hole in the finger plate, allowing it to return to its normal position. When the subscriber starts to turn the finger plate, the first thing that happens is that the shunt springs operate to short out the transmitter and receiver. As he continues to turn the finger plate, it winds up or tightens the dial drive spring. When he removes his finger from the plate, the spring drives the dial and governor, returning the dial to its normal position. As the dial returns to its normal position, it operates the pulsing springs, opening and closing them the same number of times as the number dialed. As the finger plate reaches its normal position, it operates the shunting springs, placing them in their normal position.

24. You will be responsible for a dial.

25. The finger plate serves as a guide for the subscriber preparing to dial.

26. The finger stop is provided to insure that the user turns the finger plate to the proper position while dialing each digit of a number.

27. During dialing, the pulse cam actuates the main pulse spring, making and breaking the circuit the same number of times as the digit dialed. For example, if the digit 5 were dialed, the pulse spring contact would break and make the circuit 5 times. In other words, it would open and close the circuit 5 times.

28. The shunt spring assembly (shunt contacts) disables the receiver during dialing; and, with some types of dials, the assembly also shorts out the transmitter during the dialing period.

29. During dialing, the shunt cam operates the shunt springs, disabling the receiver. Also, with some types of dials, the shunt cam operates a pair of contacts, shorting out the transmitter.

30. The speed at which the finger wheel and dial mechanism operate during the return period is controlled by the dial governor—thus, the pulse rate is regulated by the governor.

31. The telephone dial must operate at the proper speed because the telephone switching equipment operates best at this speed. If the dial operates either too fast or too slow, the switching equipment may fail to follow the dial pulses.

32. The proper dial speed for most telephone dials is 10 pulses per second.

33. A dial speed tester is normally used to check the speed of a telephone dial. However, the installer-repairman normally calls the test desk to have this check performed.

34. The dial shunt springs return to their normal position just as the finger plate reaches its normal position at the end of a dialing sequence.

35. The pulsing contacts perform in approximately the same manner in all telephones.

36. In the circuit illustrated in figure 17, the contacts between dial springs 5 and 6 function by opening the receiver circuit during the pulsing sequence.

37. In the circuit illustrated in figure 17, the closing of the contacts between dial springs 3 and 4 short out the transmitter and the primary winding of the induction coil during the pulsing sequence.

38. In the circuit illustrated in figure 17, the contacts between springs 1 and 2 will open 4 times and close 4 times when the digit 4 is dialed.

39. The 500-type telephone is most commonly used.

40. The telephones that are manufactured by Western Electric Company and ITT-Kellogg have interchangeable parts.

41. The main difference in the appearance of this dial is that the letters and numbers on the 500 telephone dial appear on the housing around the outside of the unit while on the older telephones they appear on the housing under the finger plate.

42. The handset cord for the 500 telephone has four conductors while the handset cord used with the older telephones normally has three.

43. The seven basic components used in the dial common-battery telephone are: the transmitter, receiver, dial, hookswitch, induction coil, capacitor, and ringer.

44. The carbon granules in the 500 telephone transmitter provide a more uniform contact—thus, an improvement in the quality of transmission is provided. Also, the carbon cup and diaphragm electrode are shaped in such a manner that the carbon granules cannot fall into a corner and pack.

45. The transmitter unit in the handset of the 500 telephone engages spring contacts in a plastic cup as the unit is assembled. The transmitter conductors in the handset cord are attached to the terminals of the plastic cup by screwtype terminals.

46. In addition to being a mounting for the transmitter, the plastic cup serves as an acoustic cavity back of the transmitter and as an acoustic shield between the transmitter and receiver.

47. The varistor that is connected across the receiver terminals protects the user from high acoustic levels which may be caused by stray voltages; and it also protects the receiver magnet from being demagnetized by stray voltages.

48. In the handset used with the 500 telephone, the conductors in the handset cord are attached to the receiver unit with screw-type terminals.

49. Contacts F and G on the hookswitch are used to short out the receiver when the handset is in place on its cradle.

50. When the handset is removed from its cradle, hookswitch contacts B-C and D-E close to connect the telephone lines to the network and telephone circuitry.

51. In the 500 telephone the ringer assembly uses two coils wound on one spool—older telephone ringers use two coils but each one is wound on an individual spool.

52. The entire ringer can be replaced as an assembly; or, the ringer coil, coil core, and brass gongs can be replaced individually.

53. Off-normal contacts are provided on the dial; one pair for pulsing, and the other pair for shorting out the receiver.

54. The off-normal contacts are used to short out the receiver during dialing—thus, eliminating clicks from the receiver.

55. Besides the induction coil and ringing capacitor, there are three other capacitors, three resistors, and two varistors contained in the network assembly.

56. When a network part is not functioning in a satisfactory manner, the telephone is normally repaired by replacing the network assembly.

57. The principal circuits of the 500 telephone are: the transmitter circuit, the receiver circuit, the ringer circuit, the dial circuit, and the antisidetone circuit.

58. The induction coil winding between terminals RR and R is identified by the letter-number combination P1.

59. Induction coil windings P1 and S1, in conjunction with resistor R2, form a series circuit between terminals RR and GN.

60. As shown in figure 26, the negative side of the central office battery would be connected through to terminal L2.

61. A ground symbol on a telephone wiring diagram usually means a common connection to positive battery.

62. The installer-repairman normally uses a red wire for the ring side of the line and he connects the ring conductor to the right-hand terminal on the connecting block.

63. As shown in the illustration, the yellow lead is used to complete the ringer circuit.

64. If the ringer is to operate properly, the handset must be on its cradle to open hookswitch contacts B-C and D-E. Otherwise, the ringing current would be applied to the receiving and transmitting circuitry.

65. Normal ringing current is an ac voltage of about 85 volts at 20 cycles per second.

66. This half-cycle of current would pass through the slate-red ringer lead from terminal A on the network to the 2650-ohm ringer coil.

67. When the handset is removed from its cradle, hookswitch contacts A-B and F-G break (open) and contacts B-C and D-E make (close).

68. As illustrated in figure 28, the main path of current from terminal RR to terminal C (as shown by the heavy lines) is through winding P1, the transmitter, resistor R1, and winding P2. We must not overlook the fact, however, that there is current flow between terminals RR and C via resistor R3 and varistor CR2 and also via winding P1, varistor CR1, winding S2, and winding P2.

69. The induced voice currents from the induction coil appear at terminals RR and C of the network assembly.

70. The two paths through the network that are said to be equalizer circuits extend from terminal RR to C as follows: (1) through resistor R3 and varistor CR2 and (2) through winding P1, varistor CR1, and windings S2 and P2.

71. When voice currents are received by a 500 telephone, they are applied to the induction coil windings of the network via terminals RR and C.

72. During receiving, the receiver current is induced in winding S1.

73. The induced receiver current returns from terminal R to the left-hand end of the winding S1 via four paths as follows: (1) through capacitors C2 and C1 to winding S1; (2) through resistor R2 to winding S1; (3) through varistor CR1 and capacitor C1 to winding S1; and (4) through the transmitter to terminal B and then through resistor R1, winding S2, and capacitor C1 to winding S1.

74. The term antisidetone refers to the circuit features that reduce the sidetone in the receiver circuit to a desirable level.

75. The network assembly functions as a receiving circuit when incoming voice currents are applied to terminals RR and C; and it functions as a transmitting unit by applying voice currents to the line when someone speaks into the transmitter.

76. During receiving, the voice currents that pass through windings P1, P2, and S2 produce an additive voltage in winding S1. Therefore the induced voltage is strong.

77. Winding S2 and varistor CR1 form a series circuit that is in parallel with the series circuit formed by the transmitter and resistor R1.

78. During transmission, the current through winding S2 varies in the opposite direction from the currents through windings P1 and P2. Therefore, the voltage induced in winding S1 by winding S2 is 180° out of phase with the voltage induced in winding S1 by windings P1 and P2. For this reason, the voltages induced in winding S1 oppose each other, reducing sidetone in the receiver circuit.

79. Most of the dialing current passes through the network via the following paths: (1) from terminal C through varistor CR2 and resistor R3 to terminal RR; (2) from terminal C through windings P2 and S2, varistor CR1, and winding P1 to terminal RR; and (3) from terminal C through winding P2, resistor R1, the transmitter, terminal R, and winding P1 to terminal RR.

80. Capacitor C2, in conjunction with resistor R3, forms a capacitance resistance bridge across the pulsing contacts of the dial. This acts as an arc suppressor to protect the pulse contacts.

81. The off-normal contacts of the dial are connected via the white dial leads to network terminals GN and R. This in effect places the off-normal contacts across the receiver leads—thus, shorting out the receiver during the dialing period.

82. Some of the telephones that use basically the same network circuitry as the 500 telephone are as follows: The 554, 558, 564, 565, 630, and 631 series.

83. Basically, a telephone is made explosionproof by sealing its components into a gasproof housing.

CHAPTER 4

1. General telephone maintenance may be divided into categories: preventive maintenance and corrective maintenance.

2. Preventive maintenance inspections are performed to keep the equipment in good condition and to avoid interruptions in service.

3. The associated equipment that must be inspected at the subset installation includes the pole terminals, drop wiring, protectors, station wiring, connecting blocks, etc.

4. You should inspect the drop wiring to see that it is in good condition, properly attached, and that it has sufficient clearance between it and any trees, powerlines, buildings, etc., in the area.

5. The station protector must be in good condition to offer maximum protection to the subset installation and circuit components.

6. Moisture, more than anything else, is responsible for the formation of corrosion.

7. To detect corrosion while inspecting the associated equipment at a subset installation, you should watch for any rusting, eating away of materials, corrosion around terminals caused by electrochemical reactions, and the collection or presence of moisture at any part of the installation.

8. Corrosion in subset installations is normally controlled by using shelters, covers, etc., to prevent moisture from entering the system components. Also, it is controlled in outside equipment by using materials and components that have been designed to withstand rain, snow, hot sun, etc.

9. To prevent corrosion in the subset installation, you must take into consideration the use of proper materials, both inside and outside of the building. Also, you must consider the driest routes and locations for inside wiring and components. Furthermore, you should always plan to install the right kind of equipment in a manner that will withstand the conditions at the particular installation.

10. Once corrosion has developed in a telephone installation, it is quite likely that you will have to replace some of the equipment and take the old units in for cleaning and repair. When replacing the equipment, however, you must take every precaution to prevent the recurrence of corrosion. This may include the selection of other types of instruments and perhaps the rerouting of the inside wire runs.

11. As a supervisor you must consider the prevention of corrosion during the planning of all installations. Also, you must insure that the inspections performed by your crew include examination for corrosion.

12. The four telephone operations are as follows:
    a. Signaling the operator or seizing the automatic switching equipment.
    b. Receiving the ringing signal.
    c. Transmitting sound.
    d. Receiving sound.

13. The first step in troubleshooting is a visual check, which will generally locate damaged or worn parts and wiring. Sometimes it may also locate unusual or unsafe conditions, such as a telephone wire tangled with the power line.

14. Troubleshooting procedures have been developed so that every part of the equipment can be checked, thereby allowing the job to be done with maximum effectiveness in a minimum amount of time. When the repairman resorts to a hit-or-miss procedure, he may not only overlook a vital part, but he may also get a false indication from some tested part.

15. The troubleshooting procedure serves two purposes: to locate and to prevent troubles. Since vital links in communications can be kept in service by catching trouble when it starts to develop, you should finish all troubleshooting activities completely.

16. The associated equipment (terminals, drop wiring, etc.) is more likely to give trouble than is the subset itself. Furthermore, the subset cannot function properly unless the associated equipment is in good condition.

17. The testing of circuits in the subset area should be started at some point in the circuit that is known to be good. To locate such a point, however, may require you to check the circuit at several places. To do this, try contacting the central office from different places in the circuits. For example, by using a test phone, try to contact the central office from such points as the connecting block, the station protector, or the pole terminal. When a position is located where you can contact the central office, you can then assume that the circuit is satisfactory from that point to the switching equipment.

18. When you find that a trouble is on the central office side of the pole terminal, it means that the trouble is either in the central office or that it is in the telephone cable or line. When the installer finds this to be the situation, he should then contact the central office and request that a spare pair, if available, be assigned for use with the malfunctioning subset.

19. To operate, the common-battery telephone must be connected to the central office equipment. For this reason and to insure that the subset and the central office will function as a system, the repair and testing of a subset must be coordinated with the wire chief or test desk operator.

20. When a subset fails to operate, the trouble may be in any one of three general areas: the central office, the telephone line or cable, or the subset area. For this reason, the wire chief must perform tests to determine the approximate location of the trouble before he can dispatch anyone to fix it.

21. The best approach is to first identify the trouble with one of the systems or circuits. After this, you should trace out that particular system or circuit until you locate the trouble.

22. To determine if battery is present on a telephone pair, the installer-repairman should listen for a click in the test set receiver as he connects its lead across the line or cable pair.

23. The installer-repairman can identify the ring or battery side of the line by first connecting one lead from the test set to ground and then by alternating touching the other lead to first one side of the line and then the other. A loud click should be heard in the test set receiver when the battery or ring side of the line is touched.

24. Connecting a click set to an open circuit (a point without a potential) results in no sound from the test set.

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25. The battery-powered click set is used for testing circuits that have no other source of power applied during the test.

26. Basically, the click set is constructed by connecting a telephone receiver in series with a battery. Continuity is indicated by a loud click in the receiver.

27. A loud click indicates that the circuit is complete between the conductor and ground. Therefore, the conductor is grounded.

28. To measure different amounts of voltage with the same basic meter movement, resistors with different resistance values are switched in series with the meter circuit.

29. To measure different amounts of current with the multimeter, resistors (called shunts) are switched in parallel with the basic meter movement.

30. To read ac values with a dc meter movement, the multimeter uses a rectifier unit that changes the ac to dc value before it is applied to the meter.

31. Of the multimeters described in the text, the AN/PSM-6 multimeter provides for the most accurate testing.

32. The sensitivity rating of the TS-297/U is 1,000 ohms per volt.

33. The largest voltage range provided on the TS-297/U multimeter is 1,000 volts.

34. The jack at the upper right in figure 38 (marked OHMS, -DCV, -MA, ACV) is common to all measurements performed with the meter.

35. The label RX10 located by a resistance jack means that the resistance reading on the meter is multiplied by 10 whenever the test lead is plugged into this jack for a resistance measurement.

36. The jack that is common to all measurements is used as the negative (−) lead during all dc measurements.

37. The rheostat located just below the meter on the TS-297/U is used to adjust the meter to zero during the preparation for a resistance measurement.

38. The three basic scales on the face of the TS-297/U meter are: the OHMS scale, the DCV scale, and the ACV scale.

39. The position of the selector switch on the TS-297/U multimeter determines which scale (OHMS, DCV or ACV) to read and the jack into which the red test lead is placed determines the set of numbers to read within that scale.

40. To cause the meter to deflect to about half-scale while measuring as ac voltage of approximately 200 volts, you should use the 400V jack, the selector switch should be set in the ACV position, and you should read the 0 to 40 ACV scale.

41. With the red lead plugged into the 400V jack, the selector switch set in the DCV-MA position, and the pointer on the meter pointing to 20 on the 0 to 40 DC scale, a reading of 200 volts is indicated.

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42. With the red test lead plugged into the 10V jack and the selector switch set in the DCV-MA position, you must then read the 0- to 100-DC scale as if it were 0 to 10. Therefore, an indication of 25 on the scale would be read as 2.5 volts.

43. With the test leads plugged into the proper resistance jacks (the black lead in the common jack and the red lead in one of RX jacks), the test prods must then be shorted together and the rheostat adjusted to bring the pointer on the meter to zero. If the red test lead is moved to a different RX jack during the test, the meter must then be reset to zero.

44. The power for the resistance test is furnished by a battery in the multimeter. Therefore, the unit being tested must be disconnected from its power source; otherwise, it will interfere with operation of the meter.

45. With the red lead plugged into the RX10 jack, the meter reading must be multiplied by 10. Therefore, a reading of 30 on the ohms scale is equal to 30 times 10, or 300 ohms.

46. To cause the meter pointer to deflect to approximately half-scale with a resistance value of about 200 ohms, it would be necessary that you use the RX10 jack.

47. Fifty microamperes of current are required to make the PSM-6 meter movement read full scale.

48. The PSM-6 multimeter provides two sensitivity ranges: 1000 ohms per volt and 20,000 per volt.

49. The PSM-6 multimeter has two control switches and one rheostat. The rheostat is used to adjust the meter to zero for making resistance measurements. The FUNCTION and SELECTOR switches are used to select the proper circuit elements to measure either voltage, current, resistance, or output voltage levels.

50. The maximum resistance that may be indicated by the PSM-6 multimeter is 30 megohms (3K times 10,000).

51. With the range switch in the 250 position, you would read the 0- to 2.5-DC scale. Of course, the 2.5 position would be equal to 250 volts in this case.

52. With the range switch set in the .5 position, you must read the 0 to 5 scale. However, you must add a decimal point in front of the value indicated. Therefore, the answer to this question is .3 volts.

53. When using the accessory probe to measure up to 5000 volts dc with the PSM-6, you must read the 0 to 5 DC scale.

54. The FUNCTION switch must be set in the DCV (20,000 ohms per volt) position.

55. The maximum ac voltage that can be measured with the PSM-6 is 1000 volts.

56. The OUTPUT position provides a means of measuring ac voltage without interference from any dc component that may be present on the circuit.

57. Without the accessory shunt, the maximum current that can be measured with the PSM-6 is 1 ampere.

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58. When the accessory instrument shunt is used in conjunction with the PSM-6 multimeter, the current value measured is read on the 0 to 10 scale.

59. To cause the meter to deflect to a position that can be read near the lower end of the scale, the FUNCTION switch must be set in the OHMS position and the SELECTOR switch should be set in the Ω X 10 position.

60. Sixty microamperes are indicated when the pointer points to the number 6 on the DC scale.

61. Some of the general precautions that must be observed when using a multimeter are as follows:
   a. Always read the instructions pertaining to the meter being used. This is a must if you are not familiar with the particular meter.
   b. Always start by using the highest range on the meter when the value to be measured is of unknown magnitude.
   c. Observe polarity when making direct-current measurements.
   d. Handle meter with care, operating its controls very carefully.
   e. Never try to measure the internal resistance of the meter movement.

62. When measuring current values with the multimeter, you should always make sure that the meter is connected in series with the circuit and that proper polarity is observed. Also, a large enough range must be used so that the meter will not be overloaded. Furthermore, when used as an ammeter, it must never be connected in parallel with the circuit.

63. The main precautions that should be observed when making resistance measurements are that you never connect the ohmmeter to a circuit that has voltage applied, and don't touch the terminals of the unit being measured with your hands. Remember that the resistance of your body may upset the reading if you touch the terminals during the measurement.

64. The subset ringer circuit. When a subset functions normally except for ringing, its ringer circuit is at fault.

65. Before testing the internal circuits of a subset, make a visual inspection and perform an operational test.

66. The operational tests that should be performed are the transmission and signaling tests.

67. The transmission test is performed by first removing the handset from its cradle and then by accomplishing the following:
   a. Listening for dial tone; blowing in transmitter and listening for sidetone; and turning dial slightly to see if it cuts off sidetone.
   b. Dialing the central office and listening for any unusual clicks in receiver; carrying on conversation observing quality of transmission and reception; and twisting and stretching the telephone cords to see if scratching or sizzling noises are heard.

   The signaling test is performed by first calling the central office and then by having them ring the telephone while you are listening to its ringing operation.

68. The circuits to which the trouble may be isolated are said to be the ringing, talking, receiving, dialing, and short-on-line circuits.

69. If you cannot hear dial tone in either the test set or the telephone receiver, a no dial tone situation exists, indicating a short-on-line circuit. This could mean that the line is either open or shorted.

70. When you cannot hear dial tone in the telephone receiver but you can hear it in the test set, it indicates trouble in the receiving circuit.

71. When you cannot break dial tone by dialing a number, it indicates trouble in the dialing circuit.

72. The handset inspection is performed by first unscrewing the caps and removing both the transmitting and receiving units. The units, contacts, cords, housing, etc., are then inspected very thoroughly for defects of any kind.

73. When the ringer biasing spring is broken on a late model telephone, it is the normal procedure to replace the ringer assembly.

74. In general, the hookswitch should be inspected for free operation and for spring contacts that are clean, free of pits, and that make and break the telephone circuits properly.

75. When inspecting such items as an induction coil or network assembly, the case and the windings (if they can be seen) should be examined for nicks, dents, breaks, etc. The terminals and connections must be thoroughly examined and when they appear to be satisfactory, the components should then be tested by using an ohmmeter.

76. The main points that must be checked when inspecting the dial are to see that it is securely mounted, that the finger stop and finger wheel are neither loose or bent, and that the dial operates and at the proper speed.

77. The telephone cords must be inspected for having cut or frayed insulation, for having good connections, and to see that the stays are fastened securely in the handset and telephone housing.

78. When measuring the resistance of telephone components, it is possible for other circuits or components to affect the resistance value of the one being measured. This is true especially when they are connected across the circuit.

79. Resistance readings are more accurate when the pointer on the meter indicates on the lower part of the meter scale.

80. To test the 101A induction coil with a multimeter, you must measure the resistance of each of its windings—primary, secondary, and tertiary.

81. This is not considered to be defective because the resistance values for the 101A induction coil windings are considered to be satisfactory when they don't vary more than 10 percent from the amount specified.

82. Because of the capacitors contained in it, the network assembly may still be defective even when the resistance values of all of its windings are satisfactory.

83. Since there are so many different specifications, it is not a good policy to try to remember them. It is better to get into the habit of looking up specifications, rather than trying to remember them.

84. Since the resistance of a transmitter varies with any movement of its carbon particles, a measurement of its resistance is not a very reliable test.

85. The dial contacts can be checked for continuity when closed and for properly breaking the circuit when they are open.

86. By using the ohms scale on a battery-powered multimeter, you can charge a ringing or talking capacitor first in one direction and then in the other by alternating touching the leads to the capacitor in first one direction and then in the other. While doing this, you must observe the kick on the meter each time that the leads are reversed; thus, you can get some idea as to how well the capacitor takes a charge in either direction.

87. The transmitter circuit should be tested first because troubles in the transmitting circuit can have an adverse effect on the receiving circuit.

88. The telephone transmitting circuit may be tested by connecting a test receiver and battery across the transmitter. With the circuit connected in this manner, talk into the transmitter while listening to the test receiver. If the circuit is functioning properly, the sound should come through the test receiver loud and clear. This test can easily be extended to include the components which are normally connected in series with the transmitter (dial pulsing contacts, hookswitch contacts, etc.). The test is extended by connecting the test receiver and battery across a circuit consisting of the transmitter and its series components.

89. It indicates that the circuit is open between points B and C; perhaps, the fault is in the pulsing contacts between these points.

90. If sound does not come through the test receiver when testing from point A to point B in a circuit as illustrated in fugure 44, it indicates that the circuit is open between points A and B and that the trouble is in either the RED or BLK leads or in the transmitter unit.

91. In a circuit such as shown in figure 44, if the test from points A to C is satisfactory but no sound comes through the test receiver when testing between points A and D, it indicates that the circuit is open between points C and D and the trouble is in either the lead or the hookswitch contacts between points C and D.

92. The telephone receiving circuit may be tested by connecting the test receiver and battery across the telephone receiver. If the circuit is satisfactory, a loud click should be heard in the telephone receiver at the time when the connection is made. As with the transmitter test, the receiver test can also be extended to include the components which are connected in series with the receiver.

93. If no click is heard when testing between points A and B in a circuit such as shown in figure 45, it indicates that the circuit is open between these points and that the trouble is in either the RED or WHITE leads or in the receiver unit.

94. If no click is heard when the leads of the test set are placed directly across the terminals of the handset receiver, it indicates that the receiver unit is faulty.

95. The pulsing contacts are closed when the dial is at rest.

96. The pulse spring contacts are closed; otherwise the talking circuit would be open.

97. The speed of the telephone dial is important because automatic switching equipment is normally designed to operate best at a specified speed.

98. Ten pulses per second.

99. Since the telephone dial produces 10 pulses when the digit zero is dialed, it should take 1 second for it to return to its normal position.

100. When the dial assembly is not functioning properly on the modern telephone, usually the best policy is to replace the assembly.

101. The function of connecting and disconnecting the telephone to line circuitry is common to the hookswitch operation on all telephones.

102. These shorting contacts short out the receiver when the phone is not in use.

103. A capacitor must be used in series with the ringer on the common-battery telephone to prevent battery current from flowing through the ringer.

104. With a common-battery telephone system, a shorted ringer capacitor in a subset causes a permanent signal at the central office. Of course, it will also reduce the sound quality for the subset of which it belongs since the ringer winding is in parallel to the receiver.

105. The ringer coil, coil core, and gongs are the only parts of the modern ringer that may be replaced. However, since the coil and core should not be removed unless you have facilities for recharging the permanent magnet, it is the normal procedure to replace the assembly whenever the ringer is found to be defective.

106. With the modern telephone, such components as the transmitter, receiver, hookswitch, and network assembly are normally serviced by unit replacement. That is, when the unit is found to be defective, it is replaced with a new or reclaimed unit.

STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

36254 02 22

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed*. Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

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Multiple Choice

1. (001) The major parts of the telephone handset are the

   a. transmitter and receiver.
   b. receiver and induction coil.
   c. induction coil, transmitter, and receiver.
   d. transmitter, receiver, and network assembly.

2. (002) When the carbon granules in a telephone handset transmitter are pressed together, the

   a. resistance of the transmitter increases.
   b. resistance of the transmitter decreases.
   c. voltage across the transmitter increases.
   d. current through the transmitter decreases.

3. (004) In the output of a telephone receiver, the desired wave shape in obtained by using a

   a. permanent magnet.
   b. condenser.
   c. resistor.
   d. coil.

4. (005) On the three-winding induction coil, two of the windings are called the primary and secondary. The third winding is called the

   a. P2 winding.
   b. S2 winding.
   c. sidetone winding.
   d. balancing winding.

5. (006) In common-battery telephone, the electrical power for telephone transmission is furnished by

   a. the central office.
   b. batteries in each telephone set.
   c. batteries in each telephone set and the central office.
   d. a power supply in each telephone set and the central office.

6. (007) Which of the following components is *not* used in the common-battery telephone?

   a. The ringer.
   b. The hookswitch.
   c. The induction coil.
   d. The hand generator.

7. (009) In the circuit shown in figure 10 of the text, the hookswitch contacts between terminals L2 and T are used to complete the circuit through the

   a. ringer.
   b. balancing winding and receiver.
   c. primary winding and transmitter.
   d. secondary winding and transmitter.

8. (009) During transmission, with a circuit such as illustrated in figure 10 of the text, the antisidetone circuit reduces sidetone because

   a. a closed path is provided for magnetic lines of force between the windings of the induction coil.
   b. the current in one induction coil winding is opposite to that in the other windings.
   c. the current in the primary winding is in the same direction as that in the other direction.
   d. the current in the transmitter is alternating current during transmission.

9. (010) In a common-battery dial telephone system, the chief function of the subset dial is to

a. transmit the dialed number to the switchboard operator.
b. act as a remote control for the central office switching equipment.
c. extend a connection to the called telephone via the calling cord circuit.
d. extend a connection to the called telephone via the answering cord circuit.

10. (010) In the dial telephone system, the central office equipment is ready for receiving when there is

a. a presence of dial tone.
b. an absence of dial tone.
c. an absence of busy tone.
d. a presence of normal sound.

11. (011) Refer to figure 12 of the text. To which position would the wiper move if the number 46 were dialed into the connector switch of a step-by-step dial system?

a. Upward to the 4th row, then right to the 6th terminal.
b. Right to the 4th terminal, then upward to the 6th row.
c. Upward to the 6th row, then right to the 4th terminal.
d. Right to the 6th terminal, then upward to the 4th row.

12. (013-014) Refer to figure 13 of the text. When the dial finger plate is in an off-normal position, it is *not* possible to transmit because the

a. line loop is held open.
b. pulse springs are shunted.
c. transmitter circuit is open.
d. transmitter circuit is shunted.

13. (014) In the circuitry shown in figure 13 of the text, during dialing the

a. 4-microfarad capacitor is connected directly across the dial shunt springs.
b. 4-microfarad capacitor is connected directly across the dial pulse springs.
c. 0.7-microfarad capacitor and the 100-ohm resistor form a series circuit across the dial shunt contacts.
d. 0.7-microfarad capacitor and the 100-ohm resistor form a series circuit across the dial pulse contacts.

14. (014) Refer to figure 14 in the text. Pressing touch-tone key 8 on the TTMF subset connects low- and high-frequency tones

a. 697 and 1477 to the telephone line.
b. 770 and 1477 to the telephone line.
c. 852 and 1336 to the telephone line.
d. 941 and 1336 to the telephone line.

15. (015) Electronic telephone systems convert signals between touch-tone stations and rotary dial stations with

a. linefinder equipment.
b. two-wire equipment.
c. precedence units.
d. interface equipment.

16. (015) When the digit 4 is dialed by a telephone subscriber, the dial pulsing springs interrupt the line circuit

a. four times as the dial returns to the normal position.
b. eight times as the dial returns to the normal position.
c. four times as the finger plate is pulled around to the finger stop.
d. eight times as the finger plate is pulled around to the finger stop.

17. (016) The telephone dial is used as a

a. magnetic impulse counter.
b. relay in crossbar systems.
c. toll ticketing device.
d. pulsing device.

18. (018) When using a dial-speed tester to check the speed of a telephone dial, the readings obtained are based on

a. digits per second.
b. cycles per second.
c. pulses per second.
d. revolutions per second.

19. (018) Refer to figure 17 of the text. When the dial pulse spring contacts 1 and 2 are open, line current is

a. shunted through the transmitter.
b. opposed by radio current.
c. interrupted.
d. normal.

20. (020) The handset cord used with the 500 telephone normally has

a. two conductors and a shield.
b. two conductors only.
c. three conductors only.
d. four conductors.

21. (020) In the handset used with the 500 telephone, the conductors of the handset cord are connected to

a. both the transmitter and receiver by spring contacts.
b. both the transmitter and receiver by screw terminals.
c. the transmitter by spring contacts and to the receiver by terminal screws.
d. the receiver by spring contacts and to the transmitter by terminal screws.

22. (021) Refer to figure 21 of the text. When the handset of a 500 telephone is on its cradle, hookswitch contacts

a. A and B open the receiver circuit.
b. F and G open the receiver circuit.
c. A and B short out the receiver circuit.
d. F and G short out the receiver circuit.

23. (023) What is the function of the shunt contacts for the dial of the 500 telephone?

a. Open the receiver circuit during dialing.
b. Open the transmitter circuit during dialing.
c. Short out the receiver circuit during dialing.
d. Short out the transmitter circuit during dialing.

24. (024) When testing subsets in the repair shop, if the primary winding of a 500 telephone induction circuit is found to be open, the repairman should

a. install an induction coil.
b. install a new network.
c. discard the subset.
d. repair the winding.

25. (027) When installing telephone wiring in a house, the installer-repairman will normally

a. use a red wire for the tip side of the circuit.
b. use a green wire for the ring side of the circuit.
c. connect the red wire on the right-hand terminal of the connecting block.
d. connect the green wire on the right-hand terminal of the connecting block.

26. (027) As shown by the circuitry in figure 27 of the text, the yellow conductor in the mounting cord is used to complete the

a. ringing circuit between the tip conductor and the network.
b. talking circuit between the tip conductor and the network.
c. receiving circuit between the tip conductor and the network.
d. dialing circuit between the tip conductor and the network.

27. (028-029) As illustrated by figure 28 of the text, battery current from the central office flows from network terminal

a. R to network terminal RR via winding P1.
b. RR to network terminal R via winding P1.
c. B to network terminal C via winding P2 and resistor R1.
d. RR to network terminal B via winding P1 and the transmitter.

28. (028-029) During transmission with the telephone circuitry illustrated in figure 28 of the text, the voice currents in

a. winding P1 are aided by those in winding S1.
b. winding P2 are opposed by those in winding P1.
c. both of the primary windings aid each other by inducing additive currents.
d. both of the primary windings oppose each other by inducing opposing currents.

29. (028) During receiving with the circuitry illustrated in figure 26 of the text, the voice current induced in one of the induction coil windings is applied directly to the receiver through which one of the following terminals?

a. Terminal B.
b. Terminal R.
c. Terminal GN.
d. Terminal RR.

30. (030) In regard to the 500 telephone circuit shown in figure 26 of the text, which one of the following is *not* a path for dc dialing current in the network circuitry?

   a. From terminal C to terminal RR via windings P1 and P2, resistor R1, and the transmitter.
   b. From terminal C to terminal RR via windings P1 and P2, S2, and varistor CR1.
   c. From terminal C to terminal F via windings P1, P2, S2, varistor CR1, and the dial pulse contacts.
   d. From terminal C to terminal F via windings P1, P2, S2, varistor CR1, resistor R3, and capacitor C3.

31. (031) Explosionproof telephones may be used in areas exposed to combustible gas because their

   a. network parts are gasproof.
   b. hookswitch contacts have been eliminated.
   c. internal parts are designed to eliminate arcing.
   d. internal parts are inclosed in a gasproof housing.

32. (031) The network, hookswitch, dial, ringer, transmitter and receiver, and their associated components in a weatherproof telephone are

   a. the same as the components in the 500 series telephone.
   b. bound together with cast aluminum conduit.
   c. individually inclosed in conduit.
   d. plug-in units, thus portable for use with any weatherproof set.

50. (046) Preventive maintenance inspections are performed on subset installations

   a. on a monthly basis.
   b. on an annual basis.
   c. to minimize service interruptions.
   d. to replace all obsolete equipment.

51. (046) When performing a preventive maintenance inspection in the subset area, the installer should examine the associated equipment consisting of the

   a. light wiring conduit and associated grounds.
   b. terminals, protectors, drop wiring, and station wiring.
   c. station and electric wiring inside of the building.
   d. drop and electrical facilities outside of the building.

52. (047) The best way to control corrosion in a subset installation is to

   a. replace the inside instruments regularly.
   b. clean and coat all of the connections regularly.
   c. plan its prevention as soon as the installation is completed.
   d. consider its prevention along with the planning of the installation.

53. (048) When you start troubleshooting in the subset area, one of the first steps is to

a. test the subset circuits.
b. test for voltage and continuity.
c. carefully examine the subset parts.
d. visually inspect the wiring and connections.

54. (048) When an installer-repairman is sent to check a defective substation, he should follow a step-by-step procedure. The *first* step is to

a. check the equipment for obvious faults.
b. determine the exact nature of the trouble.
c. examine the equipment for mechanical damage.
d. examine the telephone lines for mechanical damage.

55. (049) Before the installer-repairman is sent out to look for trouble in a subset area, the wire chief will normally perform tests to

a. determine the exact location of the trouble.
b. determine which substation circuit is at fault.
c. make sure that the trouble is outside of the central office.
d. make sure that the trouble is in components of the telephone subset.

56. (050) To measure various current values, the multimeter provides a means of switching different resistance values (shunts) in

a. series with the meter movement.
b. parallel with the meter movement.
c. series with the test leads and series-parallel to the meter.
d. parallel with the test leads and series-parallel to the meter.

57. (051) For measuring ac and dc values, the multimeter is equipped with

a. both ac and dc meter movements.
b. a universal meter movement for both ac and dc.
c. an ac meter movement and a converter.
d. a dc meter movement and a rectifier.

58. (051) The TS-297/U multimeter has a sensitivity of

a. 500 ohms per volt.
b. 1000 ohms per volt.
c. 20,000 ohms per volt.
d. both 1000 and 20,000 ohms per volt.

59. (052) You are measuring an ac voltage with the TS-297/U multimeter. The selector switch is set in the ACV position, the red test lead is plugged into the 400V voltage jack, and the pointer is pointing to 10 on the AC scale. How much ac voltage is being indicated?

a. 10 volts.
b. 1.0 volts.
c. 100 volts.
d. 1000 volts.

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60. (053) You are measuring dc current with the TS-297/U multimeter. The selector switch is set in the DCV-MA position, the red test lead is plugged into the 400MA current jack, and the pointer is pointing to the first mark above 20 on the DC scale. How much current is being indicated?

a. 21 milliamperes.
b. 22 milliamperes.
c. 210 milliamperes.
d. 220 milliamperes.

61. (053) To measure dc voltage, the PSM-6 multimeter provides meter sensitivity of

a. 1000 and 2000 ohms per volt.
b. 1000 and 20,000 ohms per volt.
c. 5000 and 10,000 ohms per volt.
d. 10,000 and 20,000 ohms per volt.

62. (055) On the PSM-6 multimeter, the unit of measurement (volts, current, etc.) is selected by the position of the

a. RANGE switch.
b. FUNCTION switch.
c. SELECTOR switch and the leads in the meter jacks.
d. RANGE switch and the leads in the meter jacks.

63. (055) Refer to figure 43 of the text. When using the accessory probe with the PSM-6 multimeter to measure a voltage of approximately 4000 volts dc, which meter scale must you read?

a. The 0 to 5 DC scale.
b. The 0 to 10 DC scale.
c. The 0 to 2.5 DC scale.
d. The 0 to 25 DC scale.

64. (053; 056) If you are using the PSM-6 multimeter to measure a resistance of about 3000 ohms and you want the meter to deflect to approximately half scale, in what position must you set the RANGE switch?

a. The Ω × 1 position.
b. The Ω × 10 position.
c. The Ω × 100 position.
d. The Ω × 1000 position.

65. (056) When using a multimeter to measure a voltage of unknown value, you should make the first measurement with the meter voltage RANGE switch set in

a. its lowest position.
b. its highest position.
c. a medium-low position.
d. a medium-high position.

66. (056) When using the multimeter to measure voltage and currents, you should always connect the meter

a. in series with the circuit to measure voltage.
b. in parallel with the circuit to measure current.
c. parallel to the circuit when measuring voltage and in series with the circuit when measuring current.
d. parallel to the circuit when measuring current and in series with the circuit when measuring voltage.

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67. (057) When using the multimeter to measure the resistance of a circuit, you should always

a. connect the meter parallel to the voltage in the circuit.
b. disconnect the circuit from its power source before you connect the multimeter.
c. connect the meter parallel to the current in the circuit.
d. disconnect the multimeter battery before you connect the test leads to the circuit.

68. (057) You are troubleshooting in the subset area and you have traced the trouble down to the telephone set. You should then check further by performing

a. transmission and signaling tests.
b. signaling tests and measuring the line resistance.
c. transmission tests and measuring the line resistance.
d. an external inspection and checking the subset resistance.

69. (057) The most probable symptom of transmission trouble in the telephone set is

a. excessive sidetone.
b. flashing lights.
c. abnormal sounds.
d. busy tone.

70. (058) Which of the following procedures is the best to use when you find a defective touch-tone keyset?

a. Change the frequencies for all oscillators.
b. Change the frequency for one oscillator.
c. Replace all the oscillators.
d. Replace the keyset.

71. (058) You are localizing trouble in an installed telephone by using a telephone test set connected across its line terminals. You can hear the dial tone in the test set receiver but you cannot hear it in the telephone receiver with the handset removed from its cradle. What is the problem?

a. A short-on-line condition.
b. A cannot-break-dial tone condition.
c. Trouble in the subset receiving circuit.
d. Trouble in the subset transmitting circuit.

72. (059) When inspecting the ringer assembly in a modern telephone, which of the following would necessitate replacement of the ringer assembly?

a. A loose ringer gong.
b. A broken biasing spring.
c. An open ringing capacitor in the network.
d. A shorted ringing capacitor in the network.

73. (059) The complete inspection of an induction coil or network assembly in a subset generally includes testing the

a. resistance of the windings.
b. permeability of the coil core.
c. output voltage of the secondary.
d. balancing factor of the tertiary winding.

74. (059) When inspecting the subset dial, the main test that must be performed is a

a. test of the governor spring tension.
b. test of the dial speed.
c. measurement of the contact resistance.
d. measurement of the pulsing spring tension.

75. (060) A recommended maintenance procedure for repairmen checking telephone transmitters is to

a. temporarily replace units or components to identify those that are good.
b. replace spring and relay contacts every 2 years.
c. readjust springs to check 5 grams greater every 6 months.
d. routinely move contact and relay springs to assure free movement.

76. (060) To determine if dial contacts complete a circuit, you may use an

a. HA-1 receiver.
b. F- or G-type handset.
c. AN/PSM-6 multimeter.
d. I-181 current flow test set.

77. (060) When using a multimeter to test a ringing or talking capacitor, the SELECTOR or FUNCTION switch must be set in the position required for measuring

a. resistance.
b. ac volts.
c. dc volts.
d. milliamperes.

78. (061) Refer to figure 44 of the text. If sound comes through the test receiver satisfactorily while testing from points A to B but the test receiver has no response when testing from points A to C, it indicates that the

a. red lead is open.
b. black lead is open.
c. transmitter is defective.
d. dial pulse contacts are open.

79. (062) Refer to figure 45 of the text. If a click is heard in the telephone receiver when testing from point A to point C but a click is not heard when testing from point A to terminal GN on the induction coil, it indicates that the

a. dial contacts between points B and C are open.
b. circuit through the hookswitch contacts to the induction coil is open.
c. Green lead between the hookswitch and the induction coil is open.
d. Red lead between the handset and point A is open.

80. (063) Assuming that the dial on a modern telephone is properly adjusted, how long should it take for the finger wheel to return to its normal position when you dial the number 8?

a. 0.2 second.
b. 0.4 second.
c. 0.6 second.
d. 0.8 second.

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81. (063) In practically all modern telephones, when the handset is removed from its cradle, the hookswitch functions to

a. connect the telephone circuitry to the line.
b. connect the telephone ringer into the line.
c. disconnect the telephone circuitry from the line.
d. connect the telephone protector assembly to the line.

82. (063) The capacitor connected in series with the ringer on the common-battery telephone is used to

a. change the frequency of the ringing current.
b. pass the ac ringing current through the ringer.
c. control the vibration frequency of the ringer gongs.
d. change the ringer output for people whose hearing is impaired.

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STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 300 through 318*
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301	Tools and Work Practices, pages 7-11
302	Soldering and Splicing, pages 11-14
303	Pole Climbing Equipment and Principles, pages 14-19
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CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objective: To demonstrate understanding of the general principles and work practices involved in telephone substation installation.

1. Name the telephone system components normally considered to be parts of the subset installation. (1-2, 5; Fig. 1-3)

2. Where is the station terminal-can generally located? (1-3; Fig. 2)

3. What part of the subset installation is said to be drop wire run? (1-4; Fig. 2)

4. What is the purpose of the protector used with telephone installations? (1-5; Fig. 2)

5. Why is a ground wire used with the telephone installation? (1-5)

6. Why is a connecting block used to terminate the inside telephone wiring? (1-5)

7. Why is the planning of a telephone installation important? (2-1, 3)

8. What are the main factors to be considered when planning a telephone installation? (2-2, 3)

9. Where may the specifications for wire clearances be found? (2-4)

10. What is of prime importance when considering drop wire clearances and installation? (2-5, 6)

11. In reference to telephone installation, what is meant by the term "wire clearances"? (2-4-8; Figs. 4-6)

12. What factors should be considered when planning the protector requirements for a telephone installation? (2-9, 10)

13. From the standpoint of protection requirements and as a general rule, how could you define an exposed circuit? (2-11)

14. Name two general types of station protectors and explain briefly how they operate. (2-12; Figs. 7, 8)

15. Name three types of wire which you may expect to find in an outside run. (2-14, 15; Figs. 9-12)

16. When using a combination of parallel drop and twisted pair block wire to construct an outside run, it is preferred that parallel drop wire be used on what part of the run? (2-14)

17. What are some of the factors to be considered when selecting building attachments for an outside run? (2-16)

18. Give some locations where plastic-jacketed station wire should not be used. (2-19)

19. Name three types of inside (station) wire which are commonly used in the installation of telephones. (2-19)

20. Why is the proper use of tools so important to the installer-repairman? (3-1)

21. Name three types of pliers used by the installer-repairman and give at least one use for each. (3-4; Fig. 13)

22. Why is it dangerous to use a hammer with a loose head? (3-8)

23. In what direction should the points of the teeth on a hacksaw blade face? (3-9; Fig. 15)

24. Where should the installer-repairman use a brace with exceptionally long bits? (3-13)

25. What is the main factor to be considered in selecting a screwdriver for a given job? (3-21)

26. Why must a telephone office keep accurate wire and cable records? (3-25-27)

27. Why is the telephone service order important to the installer-repairman? (3-28)

28. When installing a telephone substation, what type of information must the installer-repairman record? (3-29, 30)

29. When installing telephone substations, why is it important that the installer-repairman keep accurate records of such items as wire pairs used, man-hours expended, etc.? (3-30, 31)

30. What effect does a corroded wire splice have on a telephone circuit? (4-3)

31. How does soldering keep a wire splice from corroding? (4-3)

32. Why is acid-core solder not to be used in working with electrical circuits? (4-4)

33. In reference to soldering guns, irons, or electrical conductors, what is meant by the term "tinning"? (4-10)

34. Name two methods used in applying solder. (4-13)

35. Describe how the "sweat" method is used in applying solder. (4-14)

36. When splicing a wire pair, why should the sleeves or twisted splices be staggered? (4-17; Fig. 27)

37. What determines the size of the lineman's safety belt? (5-3)

38. By what measurement is the proper climber size determined? (5-6; Fig. 31)

39. What inspections should be performed on climbing equipment? (5-7, 8)

40. List at least five of the many safety precautions which must be observed in pole climbing. (5-9, 12, 14, 15)

CHAPTER 2

Objective: To identify the requirements for terminal-to-telephone wiring and show the degree of understanding you have of the problems involved.

1. The term "span run" refers to what part of the drop wire installation? (6-1)

2. When making a drop wire run, under what conditions may you use the existing attachments? (6-1)

3. Span clamps are used for what purpose when making a drop-wire installation? (6-2; Fig. 39)

4. What is the purpose of drop wire clamps? (6-3; Fig. 41)

5. Why is it important that slack be maintained in the drop wire at the point where it is attached to the pole and to the building? (6-3)

6. What are the purposes of drive hooks and guardarm hooks? (6-4)

7. Give some safety precautions which should be observed when using a ladder against a suspension strand to install a drop wire. (6-5)

8. When installing a drop wire span, why is it usually best to start at the building end and work toward the pole? (6-5)

9. What determines the type of attachments which must be used on a building? (6-6)

10. What types of attachments and anchors are normally used on frame buildings? (6-6)

11. Give a basic rule which helps to determine the type of attachments that should be used on frame or stucco buildings. (6-6)

12. What factors should be considered in determining the location for the first building attachment? (6-7)

13. How is the building run usually supported at the first building attachment? (6-8)

14. What types of anchors are normally used to fasten brackets, hooks, and other attachments to masonry type buildings? (6-10)

15. When an angle screw attachment is used on a building, how should it be arranged with respect to the wire pull? (6-10)

16. In reference to building runs, what is meant by "intermediate attachments"? (6-11)

17. Why does a horizontal building run of a given length require more supporting attachments than a vertical run of the same length? (6-12)

18. In reference to building runs, what is meant by the term "mechanical protection"? (6-13)

19. Name two types of insulating tubes used on building runs. (6-14)

20. Why are split type insulating tubes provided for installation work? (6-14)

21. How is building drop wire protected when it is installed behind or in front of rainspouts? (6-19)

22. When a drop wire run must turn a corner on a building, what attachments are normally used to support the wire at the corner? (6-21)

23. In reference to a building run, what is meant by the term "last attachment"? (6-22)

24. Why is a drip loop normally provided just outside of a building entrance? (6-22)

25. What determines the position in which the drive hooks must be installed on the terminal pole? (6-27)

26. How is the drop wire supported between the terminal-can and the drive hook on the pole? (6-27)

27. What determines the position in which guardarm hooks must be installed on a terminal pole? (6-28)

28. What type of drop wire is used when an underground installation is made between the terminal pole and the subject? (7-2)

29. How may underground distribution wire be protected at critical points, such as runs across roadways, small bridges, etc? (7-3)

30. What are the usual methods used in burying underground distribution wire? (7-4)

31. What are some of the most important precautions to be observed when burying distribution wire or cable? (7-5)

32. When underground cable cannot be buried deeply enough, how may it be protected at points where it is exposed to mechanical damage? (7-7)

33. How may underground wiring or cable be protected at the ends of the installation (where it enters the ground at the terminal pole and where it leaves the ground to go to the protector)? (7-9)

34. What is the main factor in determining the general location for the building entrance hole? (8-1)

35. Why should the protector be considered when planning the location of the entrance hole? (8-1)

36. With respect to the building, where is the entrance hole usually made? (8-1)

37. What determines how large an entrance hole should be? (8-2)

38. Why should entrance holes be sloped upward from the outside? (8-3)

39. Under what conditions may an entrance hole be made for an exposed system without the use of an insulating tube? (8-5)

40. What would happen if carbon dust should short across the airgap in the station protector? (8-7)

41. How does the station protector protect the equipment from excess current? (8-7)

42. How does the protector protect the equipment from excess voltage? (8-7)

43. In respect to its grounding device, where should the station protector be located? (8-8)

44. When the station protector is installed outside, where does the wiring enter and leave the protector cover? (8-9)

45. On an outside protector with both an airgap and fuses, how are the wires normally connected? (8-9)

46. Of the grounds which are usually available at an installation, which one is the most desirable for grounding the station protector? (8-10)

47. How many fuseless protectors may be grounded through a No. 14 ground wire? (8-11)

48. Why is it important for the ground connections to be just as good as any other connections in the circuit? (8-12)

49. Give some of the factors to be considered when deciding upon a location for a telephone. (9-4)

50. Why should the telephone location and the inside wire runs be planned at the same time that you plan the drop wire run and building entrance? (9-3)

51. Give some factors to be considered in selecting the route for an inside wire run. (9-7)

52. How may telephone wiring be concealed in a building without using special moldings or baseboards? (9-9)

53. Give some general rules which should be followed in making inside wire runs on the surface of walls, etc. (9-10)

54. How is wiring protection maintained for inside wiring? (9-13, 14)

55. List three situations in which the installation of building conduit would be deemed necessary. (9-18)

56. Name four general types of building conduit systems. (9-21)

57. Name two types of underfloor duct systems. (9-22)

58. Where is the telephone wiring placed in a cellular steel floor duct system? (9-23; Fig. 85)

59. What is a base raceway? (9-25)

60. What is a molding raceway? (9-27)

61. How is telephone wiring placed in underfloor conduit systems? (9-29)

62. How are underfloor duct systems installed? (9-30)

63. What types of overfloor duct are commonly used? (9-30)

64. How are connecting blocks used in telephone installation? (9-35)

65. Why are the terminals on some connecting blocks identified with the letters "R," "G," "B," and "Y"? (9-38)

66. Why is it important that the station wiring and telephone cord be properly terminated at the connecting block? (9-38)

67. How should telephone equipment be terminated? (9-38)

68. Why is a distribution terminal used in some buildings? (9-39, 40)

69. When the telephone wiring is attached to a desk, why should slack be left in the wire between the desk and the floor? (9-43)

70. In reference to telephone installation, what is meant by the term "station apparatus"? (9-41, 45)

71. When connecting telephone apparatus such as signaling equipment, transfer keys, special equipment, etc., how can you be sure that you are connecting it properly? (9-49)

CHAPTER 3

Objective: To show an understanding of the basic principles involved in handling, installing, and connecting drop wire from a building to a terminal as well as testing the completed installation.

1. Connecting the drop wires from a subset to the terminals on the terminal pole connects the subset to what? (10-1)

2. After the building runs have been completed and the subset has been connected in the building, what must be done to terminate the station at the terminal pole? (10-2)

3. Why is the span run sometimes connected to intermediate attachments between the building and the terminal pole? (10-2)

4. When the span run crosses a roadway between the pole and the building, what precautions must be taken with respect to paying out drop wire on the ground? (10-2)

5. When installing a span run from a building to a terminal pole, under what conditions should the drive hook be installed on the pole before the other placing activities are begun? (10-2)

6. After the handline has been placed over a drive hook in preparation for raising the drop wire, which end of the handline is then tied to the drop wire? (10-2)

7. During span run installation, when and where should the drop wire be cut for termination? (10-2)

8. How is the proper operating tension obtained in a drop wire span? (10-3)

9. Why should the proper amount of sag be provided in the span run? (10-3)

10. With ordinary drop wire, how much stringing sag should be placed in a 200-foot span to obtain approximately 30 pounds of stringing tension? (10-4; Table 1)

11. Give two locations where the terminals for aerial cable may be found. (10-5)

12. Why is it important that the drop wire leads be terminated at specific terminals in the terminal-can? (10-5)

13. Who is responsible for terminating the aerial cable in the terminal unit? (10-5)

14. How is the drop wire run on the pole normally supported? (11-1; Figs. 102, 103)

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15. What inspections should the installer-repairman make while terminating a drop wire at the pole terminal? (11-1)

16. Why is the terminal area on a telephone pole said to be a critical point for the installer? (11-1)

17. If you should notice a cracked or broken cable sheath while connecting the drop wire to the pole terminal, what should you do about it? (11-2)

18. Why is the drop wire run on a pole normally brought down past the terminal on one side and then up into the terminal on the opposite side? (11-5)

19. When installing a drop wire pole run, why should a clearance be maintained between the first bridle ring above the terminal and the terminal cover? (11-6)

20. When installing the pole run for a sheath-mounted terminal, the drive hook on the pole which is nearest to the terminal should be installed in what position? (11-7)

21. When terminating drop wire, why should the plain and tracer conductors be placed on specific binding posts? (11-9)

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22. When connecting drop wire leads to terminal binding posts, the plain wire should be connected to which terminal? (11-9)

23. Why are insulators used on some terminal binding posts? (11-10)

24. What kind of a telephone line may require the use of bridging connections at the terminal? (11-11)

25. When more than one drop wire must be connected to the same cable pair, how many wires are normally connected to the same terminal binding post? (11-11)

26. When four wires are bridged together, how is the connection made? (11-13)

27. When two wires are connected to the same terminal binding post, how are the wires placed in respect to the washers? (11-13; Fig. 114)

28. When a drop wire terminal is used at an open wire termination, what kind of wire is normally used between the open wires and the terminal? (12-1)

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29. What is the maximum number of wires that may normally be connected to one binding post on a drop wire terminal? (12-2)

30. What are some of the chief factors that should be considered in determining the location of a drop wire terminal? (12-3)

31. If an open wire line is mounted on pole brackets, one on each side of the pole, where should the drop wire terminal be installed? (12-3)

32. How is the bridle wire connected to the open wire line? (12-5)

33. When two drop wires are terminated at one drop wire terminal, how are they placed on the binding post in relation to washer position? (12-5)

34. When three or four drop wires must be connected to the same open wire pair, how is the connection completed? (12-5)

35. If grommets are not available for the entrance hole of a drop wire terminal, how may sealing be performed at this point? (12-5)

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36. When drive rings are placed on a crossarm to support the bridle wire, what is the maximum distance allowable between the rings? (12-5)

37. Why must operational tests be performed on a newly installed telephone set? (13-1)

38. Why is the assigned pair for a telephone installation sometimes tested at the pole terminal before the drop wire is terminated? (13-2)

39. Give some of the characteristics by which you may identify the ring conductor. (13-3)

40. When terminating a drop wire to open wire line, is it necessary to observe "ring" and "tip" polarity in making the connections? (13-3)

41. Why is ground at a positive potential with respect to the ring side of a telephone line? (13-3)

42. When using a telephone test set to verify that you have properly selected the ring conductor, why should you receive sidetone when talking into the set with it connected between ring and ground? (13-4)

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43. After termination, what tests are normally performed on a newly installed telephone? (13-5)

44. When operational tests are being performed on a newly installed telephone, what main points are checked in respect to the lines and the instrument? (13-6)

45. What does it prove if you can contact the central office on a newly installed telephone? (13-6)

46. How should you perform the ringing test on a newly installed telephone? (13-7)

47. If blowing in the transmitter of a newly installed telephone causes a scraping noise in the receiver, what would you suspect is at fault? (13-7)

48. What is meant by the performance of a noise test on a newly installed telephone? (13-7)

49. After operational tests have been completed, what must you do with respect to the telephone service order? (13-9)

CHAPTER 4

Objective: To demonstrate an understanding of the needs of the subset user and what can be done to improve service through the use of extensions and selective ringing systems.

1. What is meant by the term "selective ringing system"? (Intro.-2)

2. Why are extension ringers and loud bells provided for use with telephone subsets? (14-2)

3. How are extension ringers connected to a subset installation? (14-3)

4. Why is it important that a capacitor be in the circuit when an extension ringer or bell is connected to the inside telephone wiring? (14-3)

5. If a telephone ringer has its capacitor connected into the circuit between the ringer coils, what would be the result of connecting an extension bell (not capacitor equipped) directly across the ringer? (14-3)

6. What effect does the permanent magnet on a ringer have on ringer operation? (14-4)

7. With a telephone ringer, what moves the tapper back and forth between the gongs? (14-4)

8. What frequency ringing current is normally used with ordinary ringers? (14-4)

9. Why is a biasing spring used on some ac telephone ringers? (14-5)

10. What is meant by the term "extension telephone"? (14-7)

11. How are extension telephones normally connected to station wiring? (14-7)

12. Should an extension telephone be connected to the inside wiring circuit in the same manner as a regular telephone? (14-7, 8)

13. How does a party line differ from a line with several extension phones attached? (15-1)

14. What is the maximum number of parties that you would expect to find on a party line in a rural area? (15-4)

15. Explain the difference between selective ringing and code ringing. (15-3, 5)

16. Name three methods or systems used to obtain selective ringing. (15-6)

17. What method of selective ringing may be used without the addition of extra equipment? How many parties will this system service? (15-7)

18. On a two-party ringing-to-ground system, what is used as a common conductor for the purpose of ringing either telephone? (15-7)

19. With a two-party ringing-to-ground system, how is ringing current completely eliminated from one ring while ringing over the other line to ground? (15-9)

20. When connecting the phones for a two-party ringing-to-ground system, why does one phone require the making of more connections than the other phone? (15-10, 11, 12)

21. On a two-party line, what changes must be made in the subset installations to provide for ringing-to-ground signaling on the line? (15-10, 11, 12)

22. Basically, how does a pulsating ringing system operate? (15-15)

23. Only ringer RG3 on figure 129 fails to operate when the station switches are operated. Where is the most likely source of the trouble? (15-19; Fig. 129)

24. Switch M on figure 130 is being operated; yet RG4 does not ring. Why? (15-22; Fig. 130)

25. How is four-party selective ringing achieved with a pulsating, gas-filled tube system? (15-22)

26. What is the number of ringers that are usually connected between tip and ring with a harmonic ringing system? (15-23, 24)

27. Why is proper installation of the ringer so important with a frequency ringing system? (15-23, 24)

28. How is frequency ringing performed? (15-24, 25)

CHAPTER 5

Objective: To demonstrate understanding of some of the common causes of trouble in the subset area and the proper procedures used to locate and eliminate these trouble conditions.

1. Why does the wire chief have a responsibility in the location of telephone troubles? (16-1)

2. Name three general telephone system areas in which the trouble may be located when a subset fails to operate. (16-2)

3. When a telephone subset fails to operate, why should central office personnel test the circuit before dispatching a repairman to correct the trouble? (16-1-3)

4. Who usually operates the central office test desk? (16-6)

5. What sort of information can the test desk operator obtain for you by performing a volt-ohm-milliammeter test on a telephone line circuit? (16-6; Table 2)

6. When you are assigned to locate trouble in a subset area, how can the results of tests performed by the test desk operator help you in finding the difficulty? (17-2, 3)

7. Name four common electrical faults which are normally associated with troubles in telephone circuits. (17-3)

8. If you were assigned to locate a trouble in a specific subset area and the test desk operator informed you that a positive potential was present on the ring side of the line for this particular telephone, what would you look for in the subset area? (17-4)

9. Which conductor of a telephone pair is the negative side of the line? (17-4)

10. Which side of the line is usually connected to central office ground? (17-4)

11. When using a test set to identify tip and ring, why should a click be heard when the set is connected between ring and ground? (17-5; Fig. 135)

12. When using a test set to identify tip and ring, why is a slick click sometimes heard when the test set is connected between tip and ground? (17-5)

13. What effect on a transmission in the circuit would an intermittent open in a telephone line have? (17-7)

14. What is meant by the term "intermittent" open? (17-7)

15. Why is a trouble, such as an open telephone line, usually reported by the telephone subscriber? (17-8)

16. What is the difference between partially and completely shorted telephone circuits? (17-9, 10)

17. Will a partial short cause a telephone subset to appear dead? (17-[illegible]

18. What effect would a completely shorted drop wire have on a station telephone? (17-10)

19. In reference to telephone line pairs, what is meant by a circuit cross? (17-11)

20. Name four types of line circuit crosses. (17-11)

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21. If the ring conductor for your telephone were crossed with the tip conductor for another telephone, what would be the effect on the operation of your telephone? (17-12)

22. What is meant by the term "ring-tip" cross? (17-12)

23. Why would the results of a tip-to-tip cross be noticed by a subscriber rather than by central office personnel? (17-14)

24. If the tip conductor of your telephone were crossed with the tip conductor of another telephone, what would be the effect on the operation of your telephone? (17-14)

25. In reference to telephone work, what is meant by a line ground? (17-16)

26. Name three grounded conditions which may be found on a telephone line. (17-17)

27. What would be the results of a grounded ring conductor? (17-17)

28. Why does a completely grounded ring conductor on a telephone line prevent transmission over the circuit? (17-17)

29. What is meant by the term "swinging" ground? (17-18)

30. What information should a repairman have before he starts out to look for trouble in the subset area? (17-21)

31. When you start looking for trouble in the subset area, what are the first steps you should take? (17-22)

32. When looking for trouble in a subset area, at what point in the circuit should you make your initial test? (17-24)

33. When testing for a short in the subset area, why must the wiring on the subset side of the test point be disconnected while testing toward the central office? (17-27, 28)

34. When testing for a short in the subset area, what does it indicate if the dial tone is heard when the test set is connected to the cable terminals? (17-28)

35. When testing for a ground in the subset area, why is it necessary to identify the ring side of the line? (17-31)

36. When testing for a ground in the drop or station wiring, what is indicated if a loud click is heard as the test set is connected between the ring conductor binding post in the terminal and one of the disconnected drop wire leads? (17-31, 32)

37. When testing for an open in the station wiring, what is indicated if a loud click is heard in the test set when it is connected to the cable terminals but no click is heard when it is connected at the protector? (17-37)

38. When testing for an open in the subset area, what is indicated if a loud click is heard while testing at the protector terminals but no click is heard while testing at the connecting block? (17-37)

39. When testing for a cross in station wiring, what type of cross is indicated if a loud click is heard as the test set is connected between the tip conductor binding post in the cable terminal and the ring conductor of the disconnected drop wire? (17-41; Fig. 143)

40. When testing for a cross in station wiring, what type of cross is indicated if a loud click is heard as the test set is connected between the ring conductor binding post in the cable terminal and the tip conductor of the disconnected drop wire? (17-41, 42)

41. The station operator tells you that whenever the wind blows the quality of the service is very poor and it is difficult to understand the calling party. This is a good indication that the trouble is most likely in which portion of the substation area? Why? (18-2)

42. In regard to the trouble condition discussed in exercise 41, what should you check first? (18-2)

43. A recently installed drop has been broken by accident. What would you do to return the substation to service? (18-2)

44. You answer a trouble call from a substation for the third time. Again, you find the trouble is caused by moisture in the protector. What should you consider doing to prevent further trouble at this location? (18-3)

45. In answer to a trouble call, you have checked out the substation area thoroughly, yet you have not been able to locate the source of the trouble. What should you do next? Why? (18-5)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. The subset installation extends all the way from the terminal-can to the telephone set in the building. Not only does the subset installation include the telephone set, but it also includes the outside drop wire and brackets, the protector with its ground system and the inside wiring and connecting block. (1-2, 5; Figs. 1-3)
2. For overhead lines and cable, the terminal-can is normally located on a pole adjacent to the buildings. For underground cable, the terminal-can may be located on a pole in the area, or it may be located on a pedestal only a few feet above ground. (1-3; Fig. 2)
3. The drop wire run for a telephone installation includes the entire length of wire which extends from the terminal pole to the protector. This includes the drop from the pole to the building, as well as the drop wire run on the building. (1-4; Fig. 2)
4. A protector is used with telephone installations to protect the installed equipment (telephones, etc.) from excess voltages and currents such as may be caused by lightning, crosses with power lines, etc. (1-5; Fig. 2)
5. A ground wire is used with a telephone installation to shunt high voltages to ground at the protector and to connect certain telephone circuits to ground on some systems. (1-5)
6. The connecting block provides a method of connecting the telephone cord to the system. (1-5)
7. The planning of a telephone installation is very important because it allows the installer to plan the wire routes and to determine the materials required before the installation is attempted. To attempt an installation without previous planning is almost certain to result in costly mistakes and errors. (2-1, 3)
8. When planning a telephone installation, the location of the telephone instruments, the routing of the wire runs to provide clearance, the protector requirements, and the materials needed for the job must all be considered. (2-2, 3)
9. The specifications for wire clearances are normally found in Air Force publications pertaining to installation and in National Electric Code publications. (2-4)
10. Safety is one of the main factors to be considered in planning the drop wire installation. That is, will the drop wire be likely to cause accidents after it is installed? Also, can it be installed safely? (2-5, 6)
11. In telephone work, the term "wire clearances" has to do with the clearances maintained between telephone wiring and ground or between telephone wiring and other objects. (2-4-8; Figs. 4-6)
12. The protector requirements for a station depend mostly upon the type of system to which the station is connected. For example, if it is connected to an aerial telephone circuit or exposed to lightning, etc., the station will require greater protection than if it were connected to an underground shielded cable. (2-9, 10)
13. As a general rule, all telephone circuits involving aerial cable or open wire are classified as being exposed. (2-11)
14. The two general types of station protectors are the fused type and the fuseless type. Both of these protectors have carbon blocks separated by a small airgap. In operation, the excess voltage jumps this gap and bleeds off to ground. The fused type also contains fuses which open the circuit when excess current is applied. (2-12; Figs. 7, 8)

15. Three types of wire which may be found in outside runs are: parallel drop, twisted pair block, and twisted pair bridle. (2-14, 15; Figs. 9-12)

16. Parallel drop wire should be used between the terminal pole and the first building attachment. (2-14)

17. In selecting building attachments for an outside run, the factors which should be considered are: number of wires to be supported, building surface (frame, brick, etc.), expected storm loading, and the necessary protection of exposed wiring. (2-16)

18. Plastic-jacketed station wire should not be used where it is exposed to extreme heat or excess moisture. (2-19)

19. Three types of wire which are used in station wiring are: plastic-jacketed station wire, block wire, and cross-connecting wire. (2-19)

20. The proper use of tools is important to the performance of any job. As a matter of fact, the manner in which anyone uses tools determines to a large extent the quality of work he will do. (3-1)

21. The three types of pliers used by the installer-repairman are: the lineman's pliers, the diagonal pliers, and the long-nose pliers. The lineman's pliers are used by the installer mostly for cutting or holding wire and for crushing and stripping insulation. The diagonal pliers are used for cutting small wires. The long-nose pliers are used in bending wires for attachment to terminal lugs as well as for gripping small objects which cannot be reached with the fingers. (3-4; Fig. 13)

22. Using a hammer with a loose head is dangerous because the head may fly off and hit someone. (3-8)

23. The points of the teeth on a hacksaw blade should point away from the hacksaw handle. (3-9; Fig. 15)

24. The brace with its long bits is used by the installer to drill holes in walls, floors, etc. (3-13)

25. The main consideration in selecting a screwdriver is to find one that fits the slot in the screwhead. (3-21)

26. To install, service, and maintain telephone equipment, telephone personnel must have such information as wire pairs available, wire pairs in use, types of service, etc. For this reason, the telephone office must keep accurate records. (3-25-27)

27. The telephone service order gives the installer-repairman the authority for doing a job, and it authorizes him to obtain the necessary tools and equipment for doing the work. Also, it gives him the location of the job, the work to be done and other information. (3-28)

28. The installer-repairman must record such information as work performed, materials used, man-hours involved, wire pairs used, etc. (3-29, 30)

29. The installer-repairman must make accurate recordings to assist the telephone office in keeping accurate equipment records. Also, information recorded by the installer may be used in data analysis. (3-30, 31)

30. A corroded wire splice adds resistance to the circuit. (4-3)

31. With a properly soldered wire splice, the solder keeps oxygen away from the joint, thus preventing corrosion. (4-3)

32. Acid-core solder will cause corrosion when used in electrical circuits. (4-4)

33. The term "tinning" refers to the cleaning and coating with a thin coat of solder of such items as soldering iron tips, electrical conductors, etc. (4-10)

34. Two methods of applying solder are flow and sweat. (4-13)

35. The sweat method of applying the soldering iron tip under the joint and the solder to the top of the joint. (4-14)

36. The splices in wire pairs are staggered to prevent shorts. (4-17; Fig. 27)

37. The size of a lineman's safety belt is determined by the distance between the D-rings. (5-3)

38. The distance from the bottom of the knee bone to the underside of the shoe at the arch (less ½ inch) determines the size of the climbers required. (5-6; Fig. 31)

39. Climbing equipment should be inspected thoroughly before it is used to insure that the body belt and safety strap are in good condition and that the climbers are in such a condition as to promote safety in climbing. (5-7, 8)

40. Some of the precautions which must be observed in pole climbing are:
    a. Always make certain that your climbers and body belt are in good condition before climbing a pole.
    b. Check the condition of the pole before climbing.
    c. Always use climbers of the proper size and in the proper manner.
    d. Look up the pole while climbing to the top and down when you are descending.
    e. Always make certain that the safety-strap hook snaps into the D-ring, in the proper manner.
    (5-9, 12, 14, 15)

CHAPTER 2

1. The drop wire between the terminal pole and the first building attachment is called the "span run." (6-1)

2. It is economical to use the existing attachments if they are suitably located and are in such condition as to provide a secure mounting for the drop wire. (6-1)

3. Span clamps are used whenever it is desirable to use the aerial cable strand in supporting the drop wire. They are used in attaching the drop wire to the strand. (6-2; Fig. 39)

4. Drop wire clamps are used in connecting drop wire runs to either pole or building attachments. They are connected in such a way as to maintain slack in the wire at the point of attachment. (6-3; Fig. 41)

5. Slack must be maintained in the drop wire at its point of attachment in order to minimize conductor breakage at this point. (6-3)

6. Drive hooks are driven into telephone poles for the purpose of attaching the pole-end of the drop wire run. Guardarm hooks are bolted to either the guardarm or crossarm for the purpose of attaching the drop wire. (6-4)

7. When using a ladder against a suspension strand to install a drop wire, observe the following safety precautions:
    a. Position the ladder against the strand on the side opposite from the drop wire. Thus, pulling on the drop wire pulls the ladder against the strand rather than away from it.
    b. If the ladder is placed in a roadway, make provisions to guard the ladder from passing vehicles.
    c. Tie the ladder to the strand before starting the installation procedures.
    d. Fasten your safety belt to the strand but do not pass it between rungs of the ladder.
    e. Do not hold rope or line in your hand while climbing the ladder. (6-5)

8. Buildings runs can be installed without any interference to the ground area below the proposed span run. Also, the pulling up and sagging of drop wire from a pole or strand position is easier and safer than pulling it up from the building end. (6-5)

9. The type of building construction (wood, masonry, etc.) and the grounding of the telephone cable involved determine the type of attachments which must be used. (6-6)

10. Insulated types of attachments with screw anchor arrangements are normally used on frame buildings if the cable is not growing. (6-6)

11. A basic rule which helps to determine the type of attachments is to plan on insulating the drop wire from all combustible materials. For example, insulator type attachments should be used on frame buildings if the cable sheath is not grounded. (6-6)

12. The clearance of the span run from roadways, footways, electrical equipment, etc. must always be considered in locating the first building attachment. (6-7)

13. The building run is usually supported at the first attachment by the use of a drop wire clamp, an insulator knob and S-wire clip—or by a C-knob, in some cases. (6-8)

14. Hammer drive anchors, screw anchor arrangements, and various types of toggle bolt anchors are all used on masonry type buildings. (6-10)

15. An angle screw attachment should be installed so that the wire pull will tend to turn the screw into the wall. (6-10)

16. The term "intermediate attachments" refers to the supporting attachments used between the first and last building attachments. (6-11)

17. The supporting attachments must be placed closer together on a horizontal building run than those placed on a vertical run. (6-12)

18. Mechanical protection of a building run refers to the use of insulating tubes, tape wrappings, etc., for protecting the wiring at places where it may be damaged. (6-13)

19. Two kinds of insulating tubes are the solid and split types. (6-14)

20. Split type insulating tubes are furnished for installation on existing wiring in order to avoid cutting or disconnecting the wire to install solid tubes. (6-14)

21. When drop wiring must pass in front of or behind a rainspout, it may be protected by placing an insulating tube over the wire at the point where it comes in contact with the rainspout. Also, supporting attachments should be installed on each side of the rain spout. (6-19)

22. When the building run must turn a corner, the wiring may be supported by the use of insulated screw eyes, bridle rings, or C-knobs. In some cases, a drop wire hook may also be used. (6-21)

23. The "last attachment" on a building run is the attachment just before the wiring enters the building. (6-22)

24. A drip loop is provided in the drop wire to prevent moisture from following the wire into the building. (6-22)

25. The drive hooks must be installed on the terminal pole in a position which will provide proper appearance and clearance for the drop wire. (6-27)

26. From the drive hook on the pole, the drop wire runs through drive or bridle rings to the terminal. (6-27)

27. As is the case with drive hooks, the guardarm hooks on a pole must be installed in a position which will provide proper clearance for the wiring while making sure that the vertical run of the wire is not too loose or so tight that the wire is under additional strain. (6-28)

28. Usually a special type of distribution wire, with a steel serving and neoprene jacket, is used for underground installation. (7-2)

29. Underground distribution wire may be normally protected at critical points by the use of galvanized-pipe conduit. (7-3)

30. Underground distribution wire may be buried directly in the ground by use of a wire plow (when available) or it may be buried in a hand- or machine-dug trench. (7-4)

31. When burying underground wire or cable, the following rules should be observed:
    a. Avoid careless handling of wire or cable and do not permit vehicles to drive over wire or cable that is lying on the ground. Do not expose the wire to light or moisture until you are ready to place it in the ditch and bury it.
    b. Be sure that the wire or cable is buried deeply enough to protect it from heavy vehicles, etc. In general, a depth of 18 to 20 inches is sufficient in most cases.
    c. Check the wire or cable as it is placed in the ditch to insure that it is in good condition and that it is sufficiently long at each end for termination. When crossing ditches, avoid places where the cable might block the natural drainage of the area.

    (7-5)

32. Where underground wire or cable is exposed to mechanical damage, it may be protected by inclosing it in the exposed area with split wood conduit, galvanized pipe, or other protection. (7-7)

33. The underground wiring or cable at the ends of the installation must be protected with galvanized pipe or conduit. Usually, this protection extends from below the surface of the ground to the protector at one end and from below the ground to a height of about 6 or 7 feet at the pole end. (7-7-9)

34. The building entrance hole should be located where it will provide the shortest possible outside building run without causing inside wiring problems. (8-1)

35. Since the protector is normally located near the entrance hole and also requires a good ground, these factors should be considered when locating the entrance hole. (8-[illegible])

36. The entrance hole is usually made at a location just above the building foundation sill or through a wooden frame, around either a door or window. (8-1)

37. An entrance hole should be made large enough to accommodate the number of wires which must enter the building. If an insulating tube is to be used, the hole should be just large enough to accommodate the tube. (8-2)

38. Entrance holes should be sloped upward from the outside to help keep moisture from entering through the hole. (8-3)

39. No tube is required when a service entrance conduit is used, or when the hole is made entirely through brick or masonry. (8-5)

40. If carbon dust should short across the airgap in the station protector, it is quite likely that service on the subset concerned would be grounded out. (8-7)

41. In most cases, the protector is equipped with fuses which burn out when their maximum rating is reached. This protects the equipment from excess current. (8-7)

42. Most protectors are constructed in such a manner as to allow excess voltages to arc across an airgap to ground. (8-7)

43. The station protector should be located as close as possible to its ground source. (8-8)

44. All wiring on an outside protector enters and leaves the unit at the bottom. (8-9)

45. In the outside protector, the drop wire is normally connected to the two lower terminals; the station wiring is connected to the two outside terminals near the top; and the ground wire is connected to the center terminal at the top. (8-9)

46. The cold water pipe of a public or base water system is the most desirable ground for the protector. (8-10)

47. Only one fuseless protector may be grounded through a No. 14 ground wire. (8-11)

48. If the protector is to ground out excessive voltages, the ground system must be in good condition. Also, in many systems, the ground is a part of the ringing circuit. (8-12)

49. The telephone should be installed where it is convenient for the user. Also, it should be located where the user can hear the bell. Furthermore, it should be installed in a dry place; it should not be near a grounded metallic object such as a radiator or sink, and never near any electrical appliance. (9-4)

50. Since the telephone location and the inside wire runs will have a bearing on the location of the entrance hole, it is evident that planning of the inside installation should take place along with the planning of the drop wire run. (9-3)

51. The inside wire run should follow as direct a route as possible from the entrance hole to the telephone. However, it must also present a neat appearance and be routed around concentrations of pipes, electrical equipment, and moisture areas. (9-7)

52. Wiring may be concealed in a building by pulling it through the airspace back of the inside walls. (9-9)

53. When making inside wire runs on the surface of walls, the following rules apply:
    a. Follow the ceiling line rather than the baseboard of a room. This places the wiring above all windows and doors.
    b. Use wire moldings, picture moldings, or raceways, when available.
    c. Place the wiring in a metal or wood molding on vertical runs where door or picture moldings are not accessible.
    d. Make sure that the wiring does not interfere with the operation of windows or doors and that the wire run does not span open spaces.
    e. Do not make beam-to-beam runs in storage or work areas where the wiring may be damaged by equipment.
    f. Stay within 3 inches of the wall, if joists must be spanned.
    (9-10)

54. Wiring protection is maintained for inside wiring in much the same way as for outside wiring. Clearance from other facilities is maintained throughout the run. Various types of attachments, tape wrappings, porcelain tubes, woven conduits, etc., are all used on inside wiring to suit the job at hand. Also, with modern plastic-covered wiring, special staples with staple guns are sometimes used in attaching the wiring. (9-13, 14)

55. Conduit should be installed in a building when any of the following conditions prevail:
    a. When exposed cable or wire would be subjected to mechanical or electrical damage.
    b. When exposed cable or wire would constitute a hazard.
    c. When the appearance of exposed wire or cable would be objectionable.
    (9-18)

56. Four general types of building conduit systems are:
    a. Underfloor duct.
    b. Underfloor-from-wall conduit.
    c. Base raceway.
    d. Molding raceway.
    (9-21)

57. Two types of underfloor duct systems are:
    a. Gridwork.
    b. Cellular steel floor.
    (9-22)

58. With a cellular steel floor duct system, the telephone wire is placed in assigned ducts in the floor. Other facilities (electrical, etc.) are also assigned ducts in the same system. (9-23; Fig. 85)

59. A base raceway is simply a wall baseboard that contains channels for wiring. (9-25)

60. A molding raceway is a ceiling molding which contains channels for wiring. (9-27)

61. Telephone wiring is normally drawn into underfloor conduit systems by the use of a fishline, tape, or steel wire. (9-29)

62. Underfloor duct systems are normally installed only while a building is being constructed. (9-30)

63. Metal overfloor duct and rubber overfloor duct are commonly used in telephone installation. (9-30)

64. Connecting blocks are normally used in three different ways:
    a. To connect the line and station wires near the building and entrance when a protector is not required.
    b. To bridge station wiring.
    c. To connect station wiring to the telephone cord. (9-35)
    (9-35)

65. The letters on connecting blocks identify the terminals to aid in proper termination. (9-38)

66. When the connections are not terminated properly at the connecting block, it is quite likely that the equipment will *not* function properly. (9-38)

67. Telephone equipment should be terminated in accordance with the color code and circuit diagram for the piece of apparatus concerned. (9-38)

68. A distribution terminal is sometimes used in a building to simplify the connection of a large number of telephones. When used in an installation of this type, the distribution terminal terminates the inside (building) cable; therefore, the station wiring is connected directly to the terminal. (9-39, 40)

69. When wiring is attached to a desk, slack must be left in the wire to allow for some desk movement. (9-43)

70. "Station apparatus" refers to auxiliary telephone devices such as signaling equipment, switching or transfer keys, etc. (9-41, 45)

71. To properly connect any piece of telephone apparatus, you must follow the instructions furnished for the specific piece of equipment. (9-49)

CHAPTER 3

1. The connecting of drop wires from a subset to terminals on the terminal pole connects the subset to central office equipment via a cable pair or telephone line. (10-1)

2. After the installation has been completed at the building, the drop wire must then be placed (with proper sag) between the building and the pole and must be connected to the proper terminals in the terminal-can. (10-2)

3. To miss trees or other objects, which may be in the way, the span run is often connected to intermediate attachments such as poles, span clamps on aerial cable, etc. (10-2)

4. When paying out drop wire on the ground, precautions must be taken to keep vehicles from running over the wire. (10-2)

5. When the span is placed over a roadway where the traffic is heavy, the drive hook should be installed on the pole before starting the other placing operations. (10-2)

6. The end of the handline on the side of the drive hook nearest to the building should be attached to the drop wire. (10-2)

7. After the span run has been correctly connected to the drive hook with a drop wire clamp, the drop wire may then be shaped into the route it will follow between the drive hook and the terminal. After this has been done the wire may be cut for termination. (10-2)

8. The proper operating tension for a drop wire is normally obtained by providing the proper amount of sag in the span run at the time of installation. (10-3)

9. To provide proper drop wire clearance without excessive wire tension, the span run must be installed with the proper amount of sag. (10-3)

10. The sag should be about 7 feet. (10-4; Table 1)

11. The terminal for aerial cable is normally either located on the terminal pole or attached to the cable sheath. (10-5)

12. The drop wire leads must be terminated at the proper terminals in order that the subset will be connected to the proper cable pair. (10-5)

13. The cable is terminated at the terminal unit by cable installation personnel. (10-5)

14. The drop wire run on the pole is normally supported by intermediate attachments between the drive hook and the terminal. (11-1; Figs. 102, 103)

15. The installer-repairman should inspect the condition of outside plant equipment in all his work areas. (11-1)

16. Since the equipment in the terminal area is subject to damage, it is said that this area is a critical point for the installer. (11-1)

17. You should report it to your supervisor or to the wire chief. (11-2)

18. This method of bringing the drop wire into the terminal provides sufficient wire length for connection to any of the binding posts in the terminal unit. (11-5)

19. A clearance must be maintained above many terminals to allow for removal of the cover. (11-6)

20. The drive hook on the pole should be installed in a position so that the wires running to the terminal are in line with the terminal rings. (11-7)

21. The drop wires must be placed on specific binding posts to maintain proper "tip" and "ring" polarity throughout the system. (11-9)

22. When connecting the drop wire leads, the plain wire should be connected to the left-hand post. (11-9)

23. Insulators are sometimes used on the binding posts of important lines to help in the prevention of accidental interruptions. (11-10)

24. When several subsets are connected to the same cable pair, forming a party line, bridging connections are normally used. (11-11)

25. Normally, it is not considered good practice to connect more than two wires to any one terminal binding post. (11-11)

26. When four wires must be bridged together, it is best to use a bridging terminal of some kind to make the connection. (11-13)

27. The first wire is placed below the lower washer and the second wire is placed between the washers. (11-13; Fig. 114)

28. Bridle wire is normally used between drop wire terminals and open wire lines. (12-1)

29. Three wires, one bridle and two drop, are the maximum number that should be connected to one binding post on a drop wire terminal. (12-2)

30. The drop wire terminal must be located where it will not obstruct climbing space and where it is accessible for maintenance. The exact location may vary, along with the use of different pole attachments, crossarms, brackets, etc. (12-3)

31. When the pole brackets are on opposite sides of the pole, the drop wire terminal should be mounted between the brackets on the pole. (12-3)

32. A bridging sleeve or connector is normally used to connect the bridle wire to the open wire line. (12-5)

33. One wire of one drop wire pair is placed below the lower washer, one wire of the second drop wire pair is placed between the two lower washers, and the bridle wire is placed between the two upper washers. (12-5)

34. The connection is completed by using two drop wire terminals, one as a regular terminal and the other as a bridging terminal. (12-5)

35. The entrance hole for the drop wire terminal may be sealed by wrapping the wire with tape at the point where it passes through the hole. (12-5)

36. Drive rings should not be placed over 20 inches apart on the crossarm. (12-5)

37. Operational tests are performed on newly installed telephone sets to insure that both the line and the equipment are in proper working order. (13-1)

38. The assigned pair is sometimes tested at the pole terminal to find out if good continuity exists between the central office and the terminal. (13-2)

39. The ring conductor is the battery side of the line, and it is of negative potential with respect to either the tip side of the line or to ground. (13-3)

40. Ring and tip polarity must be observed. (13-3)

41. The tip side of the line is positive in respect to the ring conductor. Also, the tip conductor is grounded at the central office. Therefore, with the tip conductor at ground potential, the ground must also be positive in respect to the ring conductor. (13-3)

42. When the test set is connected between the ring conductor and ground, electrical energy passes from the conductor through the talk circuit to ground. Thus, sidetone is produced within the test. (13-4)

43. A newly installed telephone is normally checked by the performance of ringing, transmission, reception, and noise tests; in addition, a check is made of the dial speed on dial telephones. (13-5)

44. During operational tests on a newly installed telephone, the lines are checked for continuity, grounds, and foreign voltages. If the instrument or ringing capacitor is improperly connected, it is likely that it will show up on the test. Also, with dial telephones, the speed of the dial is checked. (13-6)

45. Basically, it proves that the telephone is working and that you have continuity from the telephone to the central office. (13-6)

46. The ringing test is a part of the routine tests which are performed on each newly installed telephone. It is performed by calling the central office for an operational check; and, when the wire chief calls you back you can observe how well the telephone rings. (13-7)

47. Usually, when blowing into the telephone transmitter causes a scraping noise, the transmitter is at fault. (13-7)

48. A satisfactory noise test is in reality the absence of noise. In other words, a telephone that has excessive noise is not functioning properly. (13-7)

49. After the tests have been completed, you must confirm the cable and terminal connections used, list the equipment and apparatus used in making the installation, and complete the service order by signing and turning it in to the telephone office. (13-9)

CHAPTER 4

1. The term "selective ringing system" refers to any system used for ringing individual telephones on a party line. (Intro.-2)

2. Extension ringers and loud bells are used to provide a means of signaling a party under adverse conditions. That is, where ordinary bells do not have sufficient coverage, or where there is excessive noise, then loud bells or extension ringers may be installed. (14-2)

3. The extension ringer is normally connected across the ringer of an existing telephone or across the line at the protector or connecting block. In any case, the extension ringer must be connected (on common battery lines) so that a capacitor is in series with the ringer. (14-3)

4. With the common-battery systems used by the Air Force, a capacitor must be connected in series with the ringer, or a permanent signal will be produced at the central office. (14-3)

5. This would cause a permanent signal at the central office because the capacitor would not be in series with the extension bell. (14-3)

6. The permanent magnet on a ringer polarizes the ringer parts. Thus, it makes the ringer more sensitive to ringing current. (14-4)

7. The tapper is moved back and forth between the gongs by the electromagnetic action of the ringer. The electromagnetic action is produced by the ac ringing current as it passes through the ringer coils. (14-4)

8. Twenty-cycle ringing current is commonly used with ordinary ringers. (14-4)

9. A biasing spring is used on some ringers to eliminate the bell tapping caused by currents other than ringing current. (14-5)

10. An "extension telephone" is an ordinary subset which is connected to an existing installation to extend the service to another room, office, or building. (14-7)

11. The extension telephone is normally connected through additional station wiring to either the protector or the connecting block. (14-7)

12. The extension telephone must be connected in the same manner as the regular telephone. That is, the same ring and tip polarity must be observed; and, when special ringer connections have been made on the regular telephone, they must also be made on the extension. (14-7, 8)

13. Extension telephones are normally used to expand the facilities of a subscriber; but party line telephones are installed to place more than one subscriber on a line. (15-1)

14. Normally, ten parties is the maximum number that may be placed on one line. (15-4)

15. With selective ringing, each subscriber on a party line hears only his own ring. With code ringing, each subscriber hears all of the rings on the line; however, the rings are coded (using numerous short and long rings) so that each party may recognize his own ring. (15-3, 5)

16. Three methods of selective ringing are: ringing to ground, pulsating ringing, and frequency ringing. (15-6)

17. The ringing-to-ground method may be used without the addition of extra equipment. However, two parties is the maximum number that may be served in this manner. (15-7)

18. Ground is used as a common conductor with the ringing-to-ground system. (15-7)

19. When ringing current is applied to one line of a ringing-to-ground system, the other line is automatically grounded at both ends. Therefore, ringing current has no effect on that side of the system. (15-9)

20. The ringer must be connected to ground in both telephones; however, the line must be reversed at the connecting block for one phone only. (15-10-12; Fig. 127)

21. To provide for ringing-to-ground signaling on a two-party line, one ringer lead in each phone must be connected to ground; the ground wire must be extended from the protector to the connecting block for each phone; and the tip and ring cord connections for one phone must be reversed at the connecting block. (15-10-12; Fig. 127)

22. With the pulsating ringing system, the central office is able to apply either positive or negative ringing pulses to either side of the line; and with a positive pulse ringer and a negative pulse ringer connected between each line and ground, the central office can ring any one of these ringers (4 in all) by applying the proper pulse to the proper line. (15-15)

23. There are several places where the trouble can exist. As all other stations are satisfactory, the trouble must be in that part of the circuit which is peculiar to RG3. If the relay does not operate, the trouble is in the central office switch or the line to station 3. If the relay operates properly, the relay contacts could be at fault. Again, if the contacts close properly, the trouble is in the ringer or that portion of the circuit. (15-19; Fig. 129)

24. Operating switch M applies positive battery to the cathode and negative to the anodes of the cold-cathode tube. Ionization does not take place, so the tube does not conduct and the bell does not ring. (15-22; Fig. 130)

25. The ringers of a pulsating, gas-filled tube system will operate only on positive or negative dc pulses, according to how they are connected. Therefore, by connecting one positive pulse ringer and one negative pulse ringer to each side of the line, four parties can be provided with selective ringing. (15-22)

26. Four ringers are usually the number used with the harmonic system. (15-23, 24)

27. A ringer which is tuned to the proper frequency must be installed at each telephone location if the system is to function properly. (15-23, 24)

28. Frequency ringing is performed by using tuned ringers which will operate only on specific frequencies; then by applying a specific frequency to the line, the desired ringer can be operated. (15-24, 25)

CHAPTER 5

1. Telephone circuit troubles have an immediate effect on the central office. Therefore, the wire chief is responsible for determining in which area the trouble is located and for the assignment of a repairman to correct it. (16-1)

2. The three general telephone system areas where trouble may be located are the central office, the line or cable, and the subset. (16-2)

3. The central office must perform tests to find out if the trouble is in the central office, the line area, or in the subset area. (16-1-3)

4. The test desk is usually operated by the wire chief or by a test desk operator. In any case, it must always be operated by a well-qualified individual. (16-6)

5. By testing the line with the volt-ohm-milliammeter, the operator can check the line loop and its resistance, determine if either side of the line is grounded, check both tip and ring for either positive or negative potential, and make various types of transmission and subset tests. (16-6; Table 2)

6. The results of tests performed by the operator should indicate whether grounds, shorts, opens, etc., are present in the circuit. In other words, these tests may give you a good indication of what the trouble is and approximately where to find it. (17-2, 3)

7. The four common electrical faults which occur in telephone circuits are shorts, opens, grounds, and crosses. (17-3)

8. Since the ring side of the line is normally negative, you should look for the source of the stray voltage in the circuit. (17-4)

9. The ring conductor of a telephone pair is the negative side of the line. (17-4)

10. The tip side of the line is usually grounded at the central office. (17-4)

11. When a test set is connected between ring and ground, it completes a circuit across the central office battery, causing a loud click in the test set. (17-5; Fig. 135)

12. Since the tip conductor is grounded at the central office and the ground potential varies at different locations, the potential difference between ground at the central office and ground at the point of test will sometimes cause a click when the test set is connected. (17-5)

13. An intermittent open in a telephone line would cause intermittent transmission if the circuit were used. (17-7)

14. An "intermittent" open is one that opens and closes the circuit intermittenly. (17-7)

15. An open telephone line has little or no effect on central office equipment. Therefore, such troubles are normally reported by the subscriber. (17-8)

16. A completely shorted telephone circuit is one in which the circuit is completely dead. With a partially shorted telephone circuit, it is possible for the circuit to operate but with difficulty. (17-9, 10)

17. A partial short may cause a subset to be partially dead. (17-10)

18. A completely shorted drop wire would cause a station telephone to appear dead. (17-10)

19. A circuit cross in a telephone system refers to the conductor of one pair being crossed with a conductor of another pair. (17-11)

20. The four types of line crosses are ring-tip, tip-ring, tip-tip, and ring-ring. (17-11)

21. This would cause your telephone pair to produce a continuous signal at the central office. Your phone may or may not be completely dead, depending upon the exact location of the cross. If your phone can be used for transmission, crosstalk will be present when your phone and the other phone concerned are in use at the same time. (17-12)

22. The term "ring-tip" cross means that the ring conductor of one pair is crossed with the tip conductor of another pair. (17-12)

23. The main indication of a tip-to-tip cross is crosstalk in the pairs concerned. For this reason, the defect is noticed by the subscriber but not by the central office. (17-14)

24. A tip-to-tip cross will cause crosstalk in the system when both pairs are in use at the same time. (17-14)

25. When a telephone line is unnecessarily connected to earth in any manner, it is said to be grounded. (17-16)

26. Three types of grounds which may be found on a telephone line are: tip to ground, ring to ground, and tip and ring to ground. (17-17)

27. A grounded ring conductor will cause a permanent signal at the central office and, depending on its location, it may or may not cause the circuit to be dead. (17-17)

28. A completely grounded ring conductor will short out the voltage which is needed for transmission. (17-17)

29. A ground with an intermittent effect is said to be a swinging ground. (17-18)

30. Before a repairman starts out to look for trouble in a subset area, he should have such information as the telephone number, the set location, the cable pair and terminal numbers, and the nature of the trouble. Also, in addition to knowing whether the station is in operation, the repairman should know if:

    - The trouble has occurred before.
    - There is any indication of foreign current on the line.
    - The current is an important one, i.e., for a hospital, doctor, etc.
    - There is a need to check the whole circuit from the terminal to the station.

    (17-21)

31. You must first verify that the trouble is as reported, and, second, you must determine whether the trouble is in the cable or in the installation wiring. (17-22)

32. The initial test should be made at a point where it is easy to open the circuit. This may be at the connecting block, the protector, or at the cable terminal. (17-24)

33. When a short exists in the station wiring, it shorts out the voltage from the central office. (17-27, 28)

34. This indicates that the cable pair is satisfactory from the terminal to the central office. (17-28)

35. Since we use the battery side of the line to test for a ground, it is evident that we must determine which is the ring and which is the battery side of the line. (17-31)

36. This indicates that the drop wire lead, to which the connection is made, is grounded. (17-31, 32)

37. This indicates that the drop wire, between the cable terminal and the protector, is defective. (17-37)

38. This indicates that an open is present in the wiring between the protector and the connecting block. (17-37)

39. A ring-to-ring cross is indicated. (17-41; Fig. 143)

40. This indicates a tip-to-tip cross. (17-41, 42)

41. If the trouble is noticed only when the wind is blowing, it is a good indication that the fault lies somewhere between the terminal and the protector. The movement of the drop in the wind is causing a swinging or high-resistance fault. (18-2)

42. First check all outside connections to make sure that they are clean and tight. (18-2)

43. As the drop is relatively new, splice in a section to replace the damaged wire. (18-2)

44. Moving the protector to a drier location. (18-3)

45. Report the situation to the wire chief. The trouble is probably in the line to the central office. (18-5)

426

STOP–

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 1 PENCIL.

36254 03 21

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

Note: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Chapter 1

1. (301) Which of the following hacksaw blades would be best for sawing thin sheet metal?

a. A blade with 24 teeth per inch.	c. A blade with 16 teeth per inch.
b. A blade with 20 teeth per inch.	d. A blade with 14 teeth per inch.

2. (300) Which, if any, of the following should be used to run a wire from a building to an outside extension ringer?

a. Plastic-jacketed station wire.	c. Block wire.
b. Cross-connecting wire.	d. None of the above.

3. (300) Why are some station protectors equipped with carbon blocks?

   a. To connect the drop wire run to the inside wiring.
   b. To shunt high voltages to ground.
   c. To shunt excess current from the fuses.
   d. To connect the ringing circuit to ground.

4. (302) When using compression sleeves to splice the conductors of a parallel drop wire, the sleeves must be

   a. fitted to the conductor with the insulation removed.
   b. fitted to the conductor insulation.
   c. soldered to strengthen the splice.
   d. staggered to strengthen the splice.

5. (300) When planning the protector requirements for a telephone installation, the protector must be used on all installations connected to

a. a ring-to-ground system.	c. underground circuits of any kind.
b. underground shielded cable.	d. aerial cable or open wire lines.

6. (303) To properly preserve the body belt and safety straps, the repairman should clean them regularly and oil them lightly with a good grade of

a. engine oil.	c. Neat's Foot oil.
b. castor oil.	d. mineral oil.

7. (300) Which, if any, of the following should be used to connect open wire circuits to pole-mounted drop wire and cable terminals?

a. Twisted pair block wire.	c. Parallel drop wire.
b. Twisted pair bridle wire.	d. None of the above.

8. (301) As a general rule, the best tool for holding and bending wires for attachment to terminal lugs is the

a. lineman's pliers.	c. combination pliers.
b. long-nose pliers.	d. diagonal pliers.

9. (300) Parallel drop wire is primarily intended for use between the

   a. terminal-can and the first building attachment.
   b. first building attachment and the protector.
   c. protector and the connecting block.
   d. telephone and the protector.

10. (302) When a wire splice is properly soldered, corrosion is held to a minimum because the

    a. strength of the joint is increased.
    b. size of the joint is increased.
    c. resistance of the splice is reduced.
    d. air is kept away from the joint.

11. (300) The telephone wiring which extends from the terminal-can to the station protector is called the

    a. block wire run.
    b. drop wire run.
    c. building run.
    d. span run.

12. (303) When wearing a body belt during pole climbing operations, a left-handed repairman should snap both ends of his safety strap to the

    a. upper D-ring when the strap is not in use.
    b. center D-ring when the strap is not in use.
    c. right side D-ring when the strap is not in use.
    d. left side D-ring when the strap is not in use.

13. (300) The connecting block in a substation installation is used for connecting the

    a. station wiring to the subset terminals.
    b. inside wiring to the subset cord.
    c. outside wiring to the protector.
    d. drop wire to the cable pair.

14. (300) The wire clearance specifications used in telephone installation are established by the

    a. National Electric Code.
    b. Communications Officer.
    c. Telephone Installer's Union.
    d. wire chief and base central office.

15. (300) Fuseless type protectors are normally used with

    a. most strand supported aerial cables.
    b. grounded sheath cable installations.
    c. open wire block and span runs.
    d. aerial drop and block wire runs.

16. (300) For overhead lines and cables, the terminal-can is normally mounted on

    a. a pole adjacent to the building.
    b. a pedestal adjacent to the building.
    c. a special support.
    d. the outside building wall.

17. (301) When the blade is properly attached to the hacksaw frame, the

    a. coarse teeth on the blade should be near the front end of the frame.
    b. fine teeth on the blade should be near the front end of the frame.
    c. teeth on the blade should point away from the handle.
    d. teeth on the blade should point toward the handle.

18. (301) For information pertaining to the availability of cable or wire pairs on your base, the installer should contact the

    a. line and cable foreman.
    b. wire records clerk.
    c. cable installation personnel.
    d. base communications officer.

19. (302) If a connection in a telephone circuit were soldered with acid-core solder, the chances are that

   a. no ill effects would be noticed in the circuit.
   b. corrosion would form, reducing the circuit resistance.
   c. corrosion would form, increasing the circuit resistance.
   d. the connection would serve its purpose as well as other connections.

20. (302) The best solder for use with telephone and electrical work is known as

   a. 50 percent solder.
   b. 60 percent solder.
   c. acid-core solder.
   d. rosin-core solder.

21. (302) If too much heat is applied to the joint during the soldering process, the melted solder will

   a. harden too slow when the iron is removed.
   b. harden too fast when the iron is removed.
   c. flow away from the joint, resulting in a loose connection when it cools.
   d. flow into the joint, resulting in a loose connection when it cools.

22. (301) The hole located near one end of the lineman's wrench is used to

   a. install the pole crossarm through-bolts.
   b. adjust the pole insulator brackets.
   c. tighten the pole steps.
   d. align the pole crossarm brackets.

23. (301) When assigned to the job of connecting two telephones to a selective ringing party line, the installer can obtain information pertaining to the type of ring for each phone by

   a. checking with central office personnel.
   b. testing the assigned pair at the terminal.
   c. testing both of the subsets.
   d. checking between the ring conductor and ground.

24. (303) It is good practice for the installer, when

   a. descending the pole, to keep the gaff about 2 inches from the pole.
   b. beginning to climb, to jab the gaff in the pole 10 inches above the ground.
   c. descending a pole, to use the same upward and outward motion in freeing the gaff as he used when climbing.
   d. climbing the pole, to look at his feet frequently to be sure not to hit a knot or other obstruction.

25. (302) In the soldering process, when the soldering iron tip is placed under the splice and the solder is applied to the upper side of the splice, the method of solder application is called the

   a. flow method.
   b. sweat method.
   c. tinning method.
   d. puddle method.

26. (303) After climbing to the desired working position near the top of a telephone pole, the lineman must place the safety strap around the pole

   a. and test the snaps, hooks, and belt by placing his weight on the assembly, with his hands on the safety strap.
   b. and test it for safety by leaning back with his hands upon his hips.
   c. before removing his weight from the climber gaffs.
   d. in a position about 10 inches from the top.

27. (303) The size of a lineman's body belt is determined by the

a. length of the belt and the distance from the buckle to the D-rings.
b. length of the belt and the size of the safety strap.
c. distance between the buckle and the eyelets.
d. distance between the D-rings.

28. (300) In reference to telephone installation, the term "wire clearance" applies

a. only to the span run.
b. only to the drop wire run.
c. to inside and outside wire runs.
d. to all wiring except the span run.

29. (303) The size of a lineman's climbers is determined by measuring from his knee bone to the underside of his shoe at the arch and then subtracting

a. 1¼ inches.
b. 1 inch.
c. ¾ inch.
d. ½ inch.

30. (301) One of the main considerations in the selection of a screwdriver is to select one that

a. has a sharp bit.
b. fits the slot in the screw head.
c. is equipped with an insulated handle.
d. is strong enough for the largest screws.

Chapter 2

31. (304) The first building attachment for a drop wire installation must be located so that the

a. protector can be mounted near the entrance hole.
b. building run will be as short as possible.
c. entrance hole can be made near the subset.
d. drop wire span will have proper clearance.

32. (306) If the airgap in a given protector is filled with carbon dust, the chances are that the associated subset will become inoperative due to

a. an open circuit.
b. a grounded circuit.
c. a crossed circuit.
d. a short circuit.

33. (304) The ends of a span run should be fastened to the attachments with drop wire clamps to minimize the

a. strain on the attachments and to keep slack out of the drop wire.
b. sag at the center of the span run and to provide slack in the drop wire.
c. strain on the drop wire at the point of attachment.
d. sag at the center of the span run.

34. (307) When an inside wire run must cross electric light wires and a separation of at *least* 2 inches cannot be obtained, the inside wiring should be protected by

a. placing it in a porcelain tube at the crossover.
b. wrapping it with rubber tape at the crossover.
c. wrapping it with friction tape at the crossover.
d. applying woven conduit at the crossover.

35. (308) When placing station wiring in a conduit system, the wiring should be

a. lubricated with mineral oil before it is pulled in place.
b. pulled through the underfloor system with a fish tape.
c. placed directly in the underfloor conduit.
d. pulled through the raceway with a fish tape.

36. (307) Why is a maintenance-free installation sought when selecting an inside wire run?

a. To increase communication efficiency.
b. To conform with regulations.
c. To conserve materials.
d. To avoid wall damage.

37. (305) Where buried distribution wire crosses a creek, the wire should be protected by

a. running it under the stream.
b. placing it in a split wood conduit.
c. treating it with a waterproof conduit.
d. placing it in a galvanized pipe.

38. (304) Mechanical protection for an insulated building run may be provided by wrapping the wire with

a. layers of insulating paper.
b. a layer of friction tape.
c. an insulating tube.
d. a layer of rubber tape.

39. (306) Airman Smith has just mounted an inside protector on a floor joist in the BX basement. From the ground locations available, Smith should select

a. a ground rod installation.
b. the pipe closest to his protector.
c. a pipe running from the water heater.
d. an incoming pipe from the base water system.

40. (305) Buried distribution wire entering or leaving the earth should be protected by a guard pipe to a depth of at least

a. 20 inches.
b. 16 inches.
c. 12 inches.
d. 8 inches

41. (304) When installing building runs, a drip loop should be provided

a. between intermediate attachments.
b. at each end of a horizontal run.
c. at each building attachment.
d. outside of each building entrance.

42. (306) When drilling an entrance hole in brick or masonry, the hole should be drilled

a. to permit the insulating tube to extend 1¼ inches beyond the wall.
b. large enough to accommodate the proposed and anticipated wiring.
c. large enough to permit the use of an insulating tube.
d. to slope downward from the outside.

43. (308) As used for inside wiring, the base raceway is

a. normally installed along the wall at floor level.
b. normally installed along the wall at ceiling level.
c. always made of wood.
d. always made of metal.

44. (304) When a ladder is used in attaching the drop wire to a cable strand, the

a. ladder should be tied to the cable strand on the side opposite from the drop wire.
b. ladder should be placed on the same side of the cable strand as the drop wire.
c. repairman should keep a handline in one hand while climbing the ladder.
d. repairman's safety belt should be attached to a ladder rung.

45. (308) Which of the following is normally used to connect the line and station wire near a building entrance when a protector is *not* required?

a. A junction box.
b. A connecting block.
c. A blank protector.
d. A special connector.

46. (304) The drop wire should be attached to the

a. terminal pole with a drive hook and drop wire clamp.
b. terminal pole with a bridle ring and drop wire clamp.
c. crossarm with a drive hook and drop wire clamp.
d. crossarm with a bridle ring and drop wire clamp.

47. (308) The use of conduit for inside wiring is *least* necessary where

a. exposed wire would be a hazard.
b. mechanical damage is likely.
c. exposed wire would be unsightly.
d. general office work is being done.

48. (306) Which of the following is applicable when ground rods are used to make an installation?

a. The location of the ground rods is of little importance.
b. Three fuseless protectors may be grounded through No. 14 wire.
c. Each protector should have its own ground rod and ground wiring.
d. There should be at least 6 inches of space between the rods when more than one rod is used.

49. (307) Which of the following is *not* a primary consideration when installing an inside wire run?

a. Clearing obstructions.
b. Minimum maintenance.
c. Length of run.
d. Service life.

50. (304) When attaching a drop wire to the terminal pole, the drive hook must be placed in a position which will provide

a. a specified vertical distance between the hook and the cable suspension strand.
b. sufficient tension in the ring wiring to remove all strain from the drop wire clamp.
c. proper sag in the span run.
d. proper clearance in the drop wire span.

51. (304) Which of the following attachments would be required to fasten a drop wire to an aerial cable strand?

a. A drop wire clamp and a drive hook.
b. A span clamp and a drop wire clamp.
c. A span clamp and a C-bracket.
d. A span clamp and a drive hook.

52. (305) When making an underground installation between the terminal pole and a building, the installer should use

a. the appropriate distribution wire, burying it either in a conduit or directly in the ground.
b. the appropriate heavy-duty wire to ground the high voltages encountered.
c. block wire, burying it directly in the ground.
d. regular drop wire, placing it in a conduit.

53. (304) If an insulating tube is required while installing a new building run, the installer should

a. secure the tube in place with lashing wire.
b. use a split-type tube, if available.
c. use a solid-type tube, if available.
d. extend the tube 2 inches beyond the ends of the entrance hole.

54. (304) The selection of the attachments for fastening the drop wire to a building is determined by the

a. particular telephone system.
b. structure of the building.
c. span portion of the drop wire run.
d. requirements for separation from inflammable or conducting materials.

55. (308) To be most effective and efficient, concealed conduit systems should be installed

a. after the building is completed.
b. by the installer-repairman when needed.
c. by electrical facilities personnel when needed.
d. while the building is under construction.

56. (307) The first step in planning an inside wire installation is to select a

a. location for the telephone set.
b. route for the inside wire run.
c. route for the protector ground wire.
d. location for the station protector.

57. (307) When inside wiring cannot be concealed and a surface run must be made, it is best to install the run

a. along the baseboard.
b. on top of the quarter round.
c. along the mopboard.
d. along the ceiling line.

58. (304) When installing drop wire runs, the installer should use

a. outside protectors on frame buildings.
b. insulated attachments on frame buildings.
c. inside protectors on brick buildings.
d. insulated attachments on brick buildings.

59. (306) The entrance hole for a drop wire should be drilled in a position to provide for the

a. proper location of the connecting block.
b. proper location of the subset.
c. shortest outside building run.
d. longest inside wire run.

60. (306) When the protector is mounted outside, it should be installed

a. within 5 feet of the ground and with its wiring entering the assembly at the bottom.
b. within 5 feet of the ground and with its wiring entering the assembly at the top.
c. at least 2 feet above the ground with its wiring entering the assembly at the top.
d. at least 2 feet above the ground with its wiring entering the assembly from either the top or bottom.

Chapter 3

61. (312) If a scraping noise is heard in the receiver while blowing into the mouthpiece of a newly installed telephone, the

a. hookswitch is defective.
b. receiver is defective.
c. coupling capacitor should be replaced.
d. transmitter should be replaced.

62. (310) Binding post insulators are used at terminal assemblies to prevent

a. accidental interruptions.
b. interruption of police calls.
c. arcing at carbon blocks.
d. wire tapping.

63. (309) When installing and terminating the drop wire span at a terminal pole, the drop wire should be cut

a. after it has been threaded into the terminal-can.
b. after it has been properly attached to the drive hook.
c. immediately after it is raised into place.
d. before it is raised into place.

64. (310) Why is the drop wiring on a pole bridged sometimes just outside of the terminal-can?

a. To connect more than one cable pair to an emergency telephone.
b. To provide extension telephone service for certain parties.
c. To provide ringing to ground for specific telephones.
d. To connect three or more parties to the same cable pair.

65. (309) How much stringing sag would be required in a 200-foot span of ordinary drop wire to obtain approximately 30 pounds of stringing tension?

a. 9 feet.
b. 7 feet.
c. 4 feet.
d. 3 feet.

66. (312) Sometimes the installer will test the assigned wire pair before he terminates the drop wire to determine if

a. sidetone is applied to the pair.
b. the tip conductor is properly grounded.
c. the central office equipment is functioning properly.
d. the pair is in good order and to identify the conductors.

67. (310) When terminating the drop wire at a pole-mounted terminal, and the binding posts for the assigned pair are located to the right-hand side of the terminal assembly, the pole run from the drive hook should be brought down

a. through the terminal assembly.
b. behind the terminal assembly.
c. past the left-hand side of the terminal assembly.
d. past the right-hand side of the terminal assembly.

68. (312) While performing an operational test on a newly terminated telephone, the tip and ring conductors from the central office to the subset are tested for

a. identification by the installer.
b. identification by the central office.
c. grounds and foreign voltages by the installer.
d. grounds and foreign voltages by the central office.

69. (312) Operational tests are performed on newly installed telephone sets primarily to

a. insure that the new installation will function properly.
b. determine if the cable pair will function properly.
c. determine if mistakes have been made during installation.
d. insure that the installation is connected to the proper cable pair.

70. (309) The stringing tension for an average length drop wire span which meets the minimum sag requirements is approximately

a. 35 pounds.
b. 30 pounds.
c. 25 pounds.
d. 20 pounds.

71. (311) When a pole run is installed for an open wire termination, the maximum spacing between intermediate attachments should *not* be over

a. 20 inches.
b. 18 inches.
c. 14 inches.
d. 10 inches.

72. (312) When a telephone line pair is in good order, and a loud click is heard when a test set is connected between one conductor of the pair and ground, this indicates that

a. a foreign current is present on the line.
b. positive battery is present on the conductor.
c. the test set is connected between ring and ground.
d. the test set is connected between tip and ground.

73. (311) If two drop wires must be bridged to one open wire pair, the conductors of the second drop wire must be terminated

a. directly to the open wire lines.
b. directly to a second drop wire terminal.
c. under the lower washers on the binding posts of the drop wire terminal.
d. between the two lower washers on the binding posts of the drop wire terminal.

74. (311) When making an open wire termination on a pole equipped with pole brackets, the drop wire terminal should be installed on the pole

a. above the lower line wire when the brackets are on the same side of the pole.
b. between the brackets when the brackets are on opposite sides of the pole.
c. below the lower line wire when the brackets are on opposite sides of the pole.
d. between the brackets when the brackets are on the same side of the pole.

75. (311) When terminating a drop wire to open wire lines, what kind of wiring is normally used between the terminal and the open wires?

a. Bridle wire.
b. Open wire.
c. Hookup wire.
d. Block wire.

76. (312) Normally, after installing a dial telephone, the operational test includes a check for

a. ringing voltage, reception, transmission, sidetone, and dial speed.
b. ringing, reception, transmission, protector operation, and dial speed.
c. sidetone, transmission, ringing, voltage, and dial speed.
d. reception, ringing, transmission, noise, and dial speed.

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77. (314) Why are some dc telephone ringers equipped with a biasing spring?

   a. To aid the energized coils in pulling the clapper in one direction.
   b. To prevent bell tapping caused by various line currents.
   c. To bias the ringer for operation on negative pulses only.
   d. To tune the ringer to a specific ringing frequency.

78. (313) Why are some ac telephone ringers equipped with a biasing spring?

   a. To bias the ringer for operation on negative pulses only.
   b. To prevent bell tapping caused by various line currents.
   c. To tune the ringer to a specific ringing frequency.
   d. To aid the magnetic field in pulling the tapper in one direction.

79. (314) With a two-party ringing-to-ground system, the subset ringer for the

   a. W-party is connected between the ring conductor and ground.
   b. J-party is connected between the ring conductor and ground.
   c. W-party is connected between the tip and ring conductor.
   d. J-party is connected between the tip and ring conductor.

80. (313) The ringing current used with an ordinary telephone ringer usually has a frequency of

   a. 40 cycles per second.
   b. 30 alternations per second.
   c. 20 cycles per second.
   d. 20 alternations per second.

81. (314) If ringer RC-4 shown in figure 130 of the text is activated, pulsating dc is being applied with the

   a. positive connected to the tip lead.
   b. positive connected to the ring lead.
   c. negative connected to the tip lead.
   d. negative connected to the ring lead.

82. (314) A pulsating ringing system, using positive and negative pulse generators in the central office and positive and negative pulse ringers in the subsets, must be connected as a

   a. tip-to-ring system to serve four parties.
   b. ringing-to-ground system to serve four parties.
   c. harmonic ring system to serve four parties.
   d. frequency ring system to serve four parties.

83. (314) The common troubles in telephone lines, cables, or substation wiring stem from

   a. breaks, crosses, grounds, and resistances.
   b. opens, breaks, resistances, and grounds.
   c. shorts, opens, crosses, and grounds.
   d. grounds, opens, shorts, and breaks.

84. (314) The two-party selective ringing system which can normally be used without the installation of additional equipment is known as a

   a. pulsating ringing system.
   b. ringing-to-ground system.
   c. harmonic system.
   d. tip-to-ring system.

85. (314) When connecting a telephone subset into a two-party ringing-to-ground system, the installer must

    a. install a ground wire from the protector to the connecting block.
    b. connect the telephone ground terminal to the tip side of the line.
    c. ground the tip conductor at the protector.
    d. ground the ring conductor at the protector.

86. (314) With modern telephone systems, the largest number of parties found on a party line is usually

    a. 4 on a rural line and 10 on a city line.
    b. 2 on a rural line and 5 on a city line.
    c. 5 on a rural line and 2 on a city line.
    d. 10 on a rural line and 4 on a city line.

87. (314) What is the major disadvantage of a multiparty line which uses selective ringing?

    a. The telephone user is disturbed by the continual ringing.
    b. The telephone line is less available for private conversation.
    c. Each extension telephone has a coded ring which causes confusion.
    d. The telephone ringers operate on different frequencies making it difficult to recognize the assigned ring.

Chapter 5

88. (316) While using a telephone test set to locate troubles at a substation installation, the results of the tests are as follows:

    1. Without disconnecting any station wiring and by connecting the test set at the pole terminal, it is *not* possible to contact the central office over the assigned pair.
    2. By disconnecting the station drop wire at the pole terminal and by connecting the test set to the terminals of the assigned pair, it is then possible to contact the central office.
    3. By disconnecting the subset cord at the connecting block and by connecting the test set at this point, it is also possible to contact the central office.

    Which of the following troubles is indicated?

    a. The drop wire run is shorted.
    b. The drop wire run is grounded.
    c. The subset and cord circuit is grounded or shorted.
    d. The station wiring is grounded or shorted at the protector.

89. (316) When ring-tip cross exists between two telephone pairs, a permanent signal will appear at the central office for

    a. the pair with its tip conductor affected.
    b. the pair with its ring conductor affected.
    c. both pairs concerned.
    d. both ring conductors.

90. (317) When testing for a cross in substation wiring, which of the following is indicated if a loud click is heard as the test set is connected between the tip conductor binding post in the cable terminal and the tip conductor of the disconnected drop wiring?

    a. A tip-ring cross.
    b. A tip-tip cross.
    c. A grounded drop wire ring conductor.
    d. A grounded drop wire tip conductor.

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WORKBOOK

Key Systems and Intercommunications

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STUDY REFERENCE GUIDE

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2. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the items missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Numbers

Guide Numbers 400 through 414

400 Introduction to Key Systems and Intercommunications; Key Telephone Systems; Intercommunications; pages 1-12

401 Operating Principles of Key System Equipment; Schematics and Their Interpretation; 1A1 Key System Operation; pages 13-19

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406 Isolating Equipment Faults; Trouble Location in Key Telephone Systems; Repairing Key System Equipment; pages 42-47

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CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To point out major features of interoffice communications equipment and identify key telephone systems. In addition, to reconsider the principles of interoffice communications equipment.

1. A 1A1 key system provides what type of communications? (1-1)

2. List the advantages that a key system has over a PBX. (1-3, 4)

3. Describe flexibility as it pertains to key systems. (1-4)

4. Where will you find the KTUs of a key telephone system? (1-6)

5. What is the name for the key system feature that connects the talking circuit of the key telephone to the central office line? (1-8)

6. How many PICKUP keys should you see on a 565 key telephone? (1-9; Fig. 3)

7. You operate which pushbutton to cause a lamp to "wink"? (1-12)

8. Describe the difference (s) between a Call Director key telephone set and a 565 key telephone set. (1-13)

9. Of what is a key system package unit comprised? (1-15)

10. What do we mean by the term "KTU"? (1-15)

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11. Identify a KTU that will operate when you depress a PICKUP key and lift the handset. (1-15, 1-18 (2))

12. If a line KTU (202D) has four relays, how many relays does the 230D have? (1-18 (2))

13. Selective signaling for a key system with an intercom is provided with what KTU? (1-18 (4))

14. Identify the unit in the 1A2 key system that compares with the R relay in the 1A1 key system. (1-20)

15. Can you install a Call Commander with a 1A2 key system? (1-20)

16. On the 1A2 system, what is the advantage of having the line circuits printed on plug-in cards? (1-20)

17. Describe a difference in the 1A1 key system and the 6A key system. (1-23)

18. Remote stations are often referred to by what other name? (2-2)

19. From where do the remote stations receive power? (2-2)

CHAPTER 2

Objectives: To specify similarities and differences in key system circuits and to make analyses of the circuit operations.

1. In a 1A1 key system, what unit controls audible and visual signals at the telephone? (3-2)

2. In what direction is current considered to flow? (3-4)

3. How do manufacturers identify the positions and use of electronic devices for the circuits of a key telephone system? (4-1)

4. Why will you find the same voltage at the line terminals for each telephone in a key system? (4-1)

5. What is the purpose of the R thermistor? (4-4)

6. Which relay controls the lock path for the R relay? (4-5)

7. What relay is released due to the operation of the thermal delay relay? (4-6)

8. What type of lamp operation will you see when a call is incoming at the key system telephone station? (4-8)

9. When a key set line circuit is being held, is the lamp off longer than it is on? (4-8)

10. Which interrupter contacts control the lamp flash? (4-8)

11. If the key telephone set lamp is operating without any interruptions, what are the conditions in the circuit? (4-9)

12. Identify the operated relays in the line circuit that cause the wink type interruption of the key telephone set lamp. (4-11 (2))

13. What resistance would you read for the winding of the H relay? (4-11 (1))

14. What action must be taken to insure an audible signal on incoming calls during a power failure? (4-12)

15. What terminal of the dial selective intercom unit provides "B" ground to the locking circuit of relay RL? (4-15)

16. List the probable digits to be used in a nine-station intercom system. (4-18)

17. Which relay in the dial selective intercom unit functions as a dial pulsing relay? (4-19)

18. What design feature prevents relays B, C, and T of the dial selective intercom unit from pulsing following the dial operation? (4-20)

19. How many times would you have to dial the assigned number if you desired to ring the intercom station for 6 seconds? (4-22, 23)

20. Identify the relays in the 207C that remain operated during conversation. (4-24)

21. Before ringing current is received, what potential is applied to the CT capacitor? (5-5)

22. Why does relay C not operate on incoming calls? (5-7)

23. What determines duration of time-out in a 400D line cord? (5-11)

24. What terminal of the 1A2 line circuit provides negative potential to the devices of the KTU? (Fig. 26)

25. Describe the circuit that lights the telephone set lamp steady when using a 1A2 key system. (5-15)

26. Which relays in the line KTU of the 1A2 system are operated while you hold the calling telephone line? (5-16-18)

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27. What terminals of the line unit (see fig. 26) will you strap to provide a wink to the telephone set lamp? (5-19)

28. Explain the major difference between a 6A key telephone system and a 1A1 key telephone system. (6-1)

29. What type of contact on the pulsing relay of the selector circuit (see FO 2) controls the operating circuit of relay B in the same unit? (6-3)

30. Describe the actions that you perform to receive dial tone. (6-5)

31. What is a wiring option? (6-7, *b* (1))

32. List two conditions that result from operating relay BC1 of the two-talking link circuit. (6-7, *b* (2))

33. How many times will the telephone ringer operate when controlled by the interrupter in a 6A key system? (6-8)

34. What circuit activities cause the called station ringer to operate, following completion of the call in progress, during camp-on? (6-13)

35. Six stations holding a conference are installed so that they are connected in what manner? (6-17; Fig. 42)

36. Which relays are normally used to provide talking battery to the 6A key system telephones? (6-21, 22)

CHAPTER 3

Objective: To specify installation planning procedures and provide information on the installation of key system cables and equipment.

1. Cite general procedures in providing a key system with intercom to a requesting agency. (Intro.; 7-1)

2. Information for making power connections is found where? (7-5)

3. What is the minimum space required on the right side of an apparatus cabinet? (8-2)

4. What is the ideal height to install the apparatus mounting for a key system? (8-2)

5. What type cable is standard for the telephones of a 1A1 key system? (9-1)

6. When wiring a terminal, should the spares be cut off? (9-1)

7. What length is considered sufficient for fanning conductors? (9-1)

8. State two advantages of terminating cable on type 66 terminals rather than on type 30 terminals. (9-1, 2)

9. What is the dialing code for the fourth telephone of an intercom system? (FO 2)

10. What color is the 12th single conductor of a cable? (Fig. 44)

11. What color is T&R, line 1, in a key cable? (9-1; Fig. 44)

12. What color code is considered to be standard in key system cables? (9-1)

13. What color would you expect pair 7 of a key system cable to be? (Fig. 44)

14. How many binder groups will you find in a 75-pair plastic-covered cable? (9-1)

15. What gauge of cable will you be most likely to install? (9-1)

16. What terminals must be wired in a key system to light the lamps under the pushbuttons? (Fig. 44)

17. What action is required to install wires on a 66 type terminal that continues on to another connection? (9-3)

18. What is a preoperational check? (9-4)

CHAPTER 4

Objectives: To analyze common test procedures for key telephone systems and methods for isolating defective key units. In addition, to point out repair methods for faulty key system components.

1. Why is it important for the installer-repairman to know the terminal strip and connecting block designations for the key telephone system at his station of assignment? (10-1, 2)

2. How would you check the operation of a newly installed key system? (10-5)

3. What digit will you dial if you desire to select your own intercom station and you are at the third telephone of the key system? (10-6)

4. How many digits should be dialed to insure good dial action? (10-8)

5. If a signal lamp is open at one key station, can the associated station lamp for the same line illuminate? (10-9)

6. In what manner should you respond when you see a lamp flashing at your station telephone during an operational test? (10-11)

7. What is the major difference between a Call Director and a six-button key telephone set? (10-12)

8. What relay in the 6A intercom is used for providing battery to the talking circuit of the primary link? (10-12)

9. What indication is provided to a 6A intercom system station attendant that a called station is busy? (10-12, *b*)

10. What is a common cause for an increase in the current of an electrical circuit? (11-3, *b*)

11. What is one method for determining if a reported trouble actually exists in the equipment? (12-2)

12. When a trouble is found to be present in your equipment, from where do you start checking? (12-2)

13. If you are getting a low-value ohm reading when testing toward the short circuit at the center of a circuit under test, what is the condition of the circuit? (12-3)

14. What is the usual cause for power circuit fuses to open? (11-1; 13-3)

15. What type trouble will most often occur in a key system? (13-3)

16. What device should a repairman use to check armature travel on a relay? (13-8)

17. In what manner are relays and switches tested and adjusted? (13-10)

18. What is the primary purpose for using new wire when "wire wrapping"? (14-2)

19. Name three advantages of solderless connections. (14-5)

20. What maximum amount of skinned wire should show between the insulation and the terminal while using a wire wrap gun? (14-6)

21. Under what conditions must you use insulated wire for cross-connecting? (14-10)

CHAPTER 5

Objectives: To analyze wiring diagrams and installation schemes; to describe operational tests of an intercommunications system and compare abnormal symptoms to the normal symptoms; and to point out how to locate troubles in the intercommunications system wiring.

1. What improvement does a newer intercommunication set have over older models? Why? (15-1)

2. What principles included with our intercommunications system description also pertain to your system? (15-3, 7)

3. Approximately what distance can separate two stations if they have a 50-ohm impedance setting and you have selected 14-gauge wire for your conductor? (Fig. 66)

4. List four things to consider when planning your intercommunications system installation. (15-3)

5. Cite a major purpose for an installation diagram. (15-5)

6. List three installation requirements you must follow when installing an intercommunications system. (16-2, 3, 5)

7. What is probably the most important requirement when checking out an intercommunications system? (17-2)

8. During an operational check, how is a desired station selected? (17-3, *c*)

9. Volume is correct when the user can speak at what distance from the unit? (17-3, *g*)

10. What action is required to converse when your helper calls from a master station? (17-4, *l*)

11. In what section of the intercommunications will you do most of your repair? (18-1)

12. Which of the following equipment checks is (are) your responsibility: weekly, monthly, daily? (18-2, 6)

13. During the repairman's scheduled inspection (check) how should he check the vacuum tubes? (18-6)

14. What three types of troubles will most likely require the use of test equipment? (18-7)

15. Identify cable conditions that you may expect to see. (18-9)

16. During a trouble location test, what is revealed to you when the speech is distorted? (18-10)

17. What further step should a repairman take if no trouble is found while troubleshooting the external wiring? (18-12)

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CHAPTER 6

Objectives: To examine the operating principles for 302 Switching Unit circuits and devices; to point out the connections that result in circuit operation; and to specify maintenance procedures used with this switching unit.

1. List controls at the assistant controller's position that have the same nomenclature as that of a key system telephone. (19-2)

2. Assume that you are leaving the van and have no replacement assistant controller. Now, identify the key at the assistant controller's position and the selection that you make for this switch before you leave. (19-2)

3. What telephone system arrangement permits a lifted handset at the telephone to connect with, and signal, the assistant controller? (19-3)

4. How many loudspeakers will you expect to find in the operations van? (19-3)

5. Which colored key is used by the tower operator for requesting attention? (19-9)

6. Identify the switch or switches that must be operated to light the COM lamp. (19-12, 14)

7. You have maintenance responsibility for how many panel lamps at the control tower? (19-15; Fig. 69)

8. Where will you find the 834A networks and CO relays which serve the tower operators? (20-3)

9. Identify four equipment units that are installed on the J53033C equipment cabinet in the power van. (20-3; Fig. 73)

10. According to figure 72, what type of signaling arrangement is provided for the station line circuits? (20-4; Fig. 72)

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11. How many one-way voice circuits are installed between the operations van and the control tower? (20-4)

12. Foldout 5 shows what components form the series operating circuit of relay SL? (20-6; FO 5)

13. Identify the current that operates the relay which completes the ringing circuit to the called telephone station, and describe the current that signals this called station. (20-9; FO 5)

14. Using FO 5 as your guide, will you find the H relays for the same telephone circuit installed in the same unit? (20-11; FO 5)

15. What relay can be considered as the "precondition" relay for operating the controller's control switches and their associated equipment? (20-6, 15; FO 5)

16. List the devices that form the complete circuit which operates relay CT. (20-15, 16; FO 7)

17. Which relay contacts shunt capacitor P12 when the 302 Switching Unit has a power failure? (20-20; FO 7)

18. What will you do to release the operated H relay in a station line circuit? (20-12, 21; FO 5)

19. In the J53033M unit, what device is connected to a ground terminal and extends this ground potential to the FL1 relay, thereby enabling the relay to operate? (20-24, 25; Fig. 82)

20. What relay in the dark environment control circuit operates following your placing the LP CONT switch at OFF? (20-30; FO 4)

21. What effect will an operated CO relay in the dark environment control circuit have on the potential for the D leads? (20-30; FO 4)

22. Identify the relay contacts that cause the colored lamps to flash during a 302 Switching Unit request condition. (20-32; FO 6)

23. Research FO 6 and list the connections between contacts 5 and 6 at the AMBER key and relay K2. (20-29, 35; FO 6)

24. List the order in which you use the request pushbuttons when doing a performance test. (19-7-9; 20-37)

25. List the two methods that you have to use when extinguishing the colored lamps. (20-37, 38)

26. 302A system maintenance is divided into what four broad categories? (21-2)

27. Individual components are not normally isolated to be tested, but are proven good or bad in what manner? (21-8)

28. Green workcards provide information on what type of routines? (21-9)

29. What action is recommended if a repairman finds a faulty 623A key unit while troubleshooting? (21-13)

30. What means is used to insure mating of a cable to its proper receptacle? (21-22)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. A 1A1 key system provides specialized telephone communications for offices within the same organization.
2. A key system allows each user to perform functions that a PBX attendant would provide. For example, holding calls, signalling, and supervision. Therefore, no attendant is needed.
3. A key system is flexible because it has features that enable any station to be large or small and to differ from any other station. This variety of features is provided by simply adding or changing key units.
4. To troubleshoot a KTU, you must look in the equipment cabinet.
5. The PICKUP key connects the talking circuit key telephone to the central office line.
6. The 565 key telephone has five PICKUP keys and one HOLD key.
7. Depressing the HOLD pushbutton results in a winking lamp. Of course, other activities had to precede this action, but these procedures have yet to be described. Chapter 2 will disclose them.
8. The Call Director has a greater number of pushbuttons for connection to communication lines and the construction is slightly different. Accordingly, the appearance of the sets differs greatly.
9. A key system package unit usually includes a combination of key telephone units, a power supply, and internal cabling. Additional cabling is provided if ordered by the installer.
10. KTU designates the individual unit consisting of relays and allied equipment needed to perform specific services.
11. A 202D or 230B will operate when you depress a PICKUP key.
12. Since the 230B has four times as many lines as the 202D, it would have at least 16 relays.
13. Selective signaling for a key system intercom is provided with a 207C KTU.
14. The Q1 transistor is the comparable ring control device in the 1A2.
15. Yes. Any key telephone used with a 1A1 system is usable with the 1A2 system.
16. The card is easily removed and replaced during a troubleshooting procedure.
17. The 6A is strictly an intercom system. The 1A1 key equipment is a central office line control system.
18. Remote stations are often referred to as "slave" stations.
19. Remote stations receive power from the master stations.

CHAPTER 2

1. The 232B KTU controls all audible and visual signaling at the telephone.

2. Current is considered to flow from negative to positive in telephone circuits.

3. Key telephone system manufacturers use symbols to show electronic devices and their position in a circuit.

4. You learned in Volume 1 that voltage is the same at each branch of a parallel circuit; therefore, the same voltage will be present at the line terminals of each phone since they are parallel connected.

5. Thermistor R prevents false operation of the R relay due to its resistive characteristics.

6. The lock path for relay R is completed through contacts of the AH relay.

7. Relay R in the line circuit releases following the operation of the thermal delay relay.

8. An incoming call at a key system telephone is indicated by a flashing lamp.

9. No. The lamp is on 0.475 second and off for 0.025 second.

10. Interrupter contacts 4 and 5 control the lamp flash circuit.

11. Relays A and AH are operated in the 202D or 230B KTUs.

12. The AH and H relays in the line circuit make the contacts that complete the circuit for winking lamps.

13. You would find a reading of 180 ohms at the H relay coil.

14. No audible signal is possible during power failure unless you bridge a ringer across tip and ring of the line.

15. Terminal 20B of the 207C provides ground.

16. A nine-station intercom system would logically have the digits 2, 3, 4, 5, 6, 7, 8, 9, 0. Digit 1 is not used.

17. Relay A in the 207C is the dial pulsing relay.

18. Relays B, C, and T of the 207C are designed with RC networks or special windings which make them slow to release, and thus not follow the dial pulses.

19. By dialing the selected station four times, you permit a 6-second ring, 1.5 second per ring.

20. Relays A and B remain operated during conversation.

21. The CT capacitor is charged to approximately −16 volts while the line circuit is idle.

22. Relay C cannot operate due to resistor R11 limiting the current through its windings.

23. Duration of time-out is determined by the discharge time of the CT capacitor.

24. Terminal 17 of the line KTU in the 1A2 key system provides negative battery for the circuit devices.

25. The lamp circuit in a line card KTU includes contact M1 of the A relay and M1 of the C relay, in addition to the line connections to the telephone.

26. Relays B, C, and L of the line KTU operate when the HOLD button is depressed in a 1A2 key system.

27. You must strap terminal 10 to terminal 9 on the 1A2 line unit to provide the lamp wink feature.

28. A 6A key system only provides intercommunications between stations within an organization, whereas the 1A1 system can do this in addition to permitting calls to nonorganizational stations, i.e. central office lines.

29. A "make" type contact on relay A of the 207C controls the operating circuit of relay B.

30. You must depress the INTERCOM key and lift the handset to get dial tone.

31. A wiring option is a point in an electrical circuit where you may choose one of two or more ways to connect wiring.

32. Operated BC1 releases relay BC, increases current for relay LS, and opens the operate path of relay TB1.

33. The bells will ring intermittently until answered or abandoned.

34. Relay BY restores following subscriber hangup, opening the circuit that held relay T in the selector unit. A path is then complete to operate relay RL through contacts M4 of the T, which releases slowly. Relay RL, operating, will operate the TR relay, thus completing the connections for the ringer at the called station.

35. Key telephones are always connected in parallel.

36. Relays TB1 and TB2 supply the talk battery for the telephones of a 6A key system.

CHAPTER 3

1. To provide a key system with intercom to a requesting agency, you must determine what its requirements are, consider what equipment is available that provides the desired features, and prepare installation specifications for the selected equipment. Of course, there are additional duties to perform. For example, installing the cables and the selected equipment, and making a preoperational inspection and operational test.

2. Power connections information is found on the Key System Strapping Sheet.

3. One foot of clearance is required to open the gate unhindered.

4. The proper height to mount an apparatus cabinet is approximately eye level to an average man.

5. 25-pair 24-gauge plastic cable is considered standard.

6. Spares should always be saved for future use.

7. Six inches is adequate length for fanning conductors.

8. Type 66 terminals allow easier, faster termination.

9. The dialing code for the fourth station would be 5, since digit 1 is not used.

10. The 12th single conductor of a connector cable is blue with a red tracer, as shown in figure 44.

11. Ring of pair 1 in a key system cable is blue, while tip of the same pair is white.

12. The D color code is considered standard, and used most often.

13. Pair 7 of a key system cable should have conductors with orange- and red-colored insulation, as shown in figure 44.

14. A 75-pair plastic-covered cable has three binder groups which use a blue, an orange, and a green binder wrapping.

15. 24-gauge wire is used most often and considered standard.

16. Terminals 5 and 6, terminal strip "A," is used for lamp (L) and lamp ground (LG).

17. When installing conductors that continue on to another point, the 714B blade must be reversed.

18. A close examination of a newly installed system is sometimes referred to as a "preoperational check."

CHAPTER 4

1. The installer-repairman is responsible for making a system operate and keeping it operating; therefore, he must be familiar with the terminal connections for the equipment at his installation.

2. A newly installed telephone system should be checked out by testing each telephone in the system to see that it functions properly during each feature of operation.

3. To select your own telephone when testing from the third intercom station you dial the digit 4.

4. Only one digit is required to determine if a dial is good.

5. The lamps are connected in parallel. Therefore, if you recall your previous experiences and the information of this chapter, you know that a lamp in parallel with others can burn out and not affect the others.

6. When a lamp is flashing at your station during an operational test, you should depress the button containing that lamp and lift the handset.

7. A Call Director telephone functions the same as the six-button key telephone set except that it has a greater number of buttons.

8. Relay TB1 in the 6A intercom system provides battery for the first (primary) talking circuit.

9. A 6A intercom system station that attemps to signal a second, but busy station, receives busy tone.

10. You can expect to find an increase in circuit current when resistance is short-circuited.

11. You can verify if the reported trouble exists by operating the equipment.

12. You should start looking for the trouble from the unit in trouble.

13. A low-value ohm reading when testing toward the short circuit near the center of the circuit indicates that that section of the circuit is not open.

14. Circuit fuses open as a result of an increase in current in an electrical circuit. This is often referred to as an overload.

15. Most of the troubles you will encounter will be of a mechanical type, i.e. contact adjustment.

16. A feeler gauge should be used to measure armature travel.

17. Relays must be tested electrically and adjusted mechanically.

18. In many cases, rewrapping an existing wire will cause it to break.

19. Advantages of solderless connections are that they are safer, faster, and cheaper.

20. No more than 1/16 inch of skinned wire should show between terminal and insulation.

21. Insulated wire must always be used for cross-connecting if there is any possibility of short-circuiting.

CHAPTER 5

1. Intercommunication sets are smaller because solid-state devices are used rather than vacuum tubes.

2. Principles of installing, operating, and maintaining intercommunications equipment apply to all systems.

3. Using 14-gauge wire between your stations extends the distance between two stations to approximately 12,000 feet.

4. Four things to consider when planning your installation are: (1) How many stations are required; (2) is the system to be expanded; (3) are any of the stations to be located in wet or hazardous areas; and (4) what is the total length of the cable run.

5. An installation diagram is useful for reference purposes. Men referring to it include supervisors. presently assigned repairmen, and subsequent assignees.

6. You must place your intercommunications equipment (1) where it will perform most effectively, (2) where it won't be a safety hazard, and (3) where it won't be subject to destruction.

7. An operational checkout of an intercommunications system must include a test of all stations and each function at the station.

8. A station is selected by operating the associated selector key to the up position (ON)?

9. Volume should be at a proper level if the user can be heard clearly while speaking 12 to 18 inches from the unit.

10. If your helper calls from a master station, you may remain in the IDLE position while conversing.

11. Your repair actions will be taken in the external wiring portion of the system.

12. The monthly check is the responsibility of an installer-repairman.

13. The repairman checks for looseness or cracks.

14. Locating shorts, grounds, and crosses usually require the use of test equipment.

15. Cables may appear to be solidly connected, to have no sharp bends, and to be neat and properly in place. However, they may have sharp bends at the terminals, or have shorts, opens and crosses from unwarranted twisting at the sheath and excessive strain at the terminals.

16. Speech distortion is caused by double amplification; most often, the fault of the operator.

17. If the repairman finds no fault in the external wiring, he should then report all symptoms and findings to radio maintenance personnel.

CHAPTER 6

1. The assistant controller's position includes LINE lamps. PICKUP and HOLD keys, and a dial, which were also listed for a key system telephone.

2. Before you leave your assistant controller's position, place the controller's OFF-WIRE-RADIO key at OFF or RADIO.

3. The direct line arrangement in a telephone system permits the connection and signaling of a station by lifting a telephone handset.

4. One loudspeaker is installed in most operations vans.

5. The tower operator gains the attention of the controller by pressing the RED request button.

6. You must operate the ON and COM switches to light the COM lamp.

7. You have maintenance responsibility for 16 panel lamps at the control tower.

8. The equipment that serves the tower operators is installed in the apparatus cabinet.

9. The J53009CW-2, J53009CY-1, J53009CR, and J53009CU units are installed on the J53033C equipment cabinet in the power van.

10. The station line circuits are developed to provide two-way signaling.

11. Three one-way voice circuits are installed between the operations van and the control tower.

12. Contacts of the LINE key, contacts BM12 of relay CR1, and contact 1 of relay WT1, and the windings of relay SL form the series operating circuit of relay SL.

13. Direct current operates the FR relay which completes the ringing circuit to the called station. Alternating current rings the bells of the telephone at this called station.

14. Since one H relay is in the station line signaling circuit and the second is shown in the line selection circuit, it is evident that they are in different units (J53033S and J53009CW).

15. Relay WT1 can be considered as the "precondition" relay for operating the controller's switches and their associated equipment.

16. Contacts 3 and 4T of relay C1, contacts A and 1 of relay CB, and contacts 3 and 4B of relay RS form the operating circuit for relay CT.

17. Contacts 1B and 2 of released relay AB shunt capacitor P12 when the 302 Switching Unit has a power failure.

18. You should depress the LINE key for the station being held operated in order to restore the H relay.

19. Contact 4T of relay A is connected to a grounded terminal for the purpose of operating relay FL1.

20. The CO relay in the dark environment equipment operates when the LP CONT switch is off.

21. The operated CO relay in the dark environment equipment replaces a voltage at the D leads with a ground potential.

22. Contacts 4 and 8 of relay FL provide the colored lamp flashing circuits during a request action.

23. Between relay K2 and contacts 5 and 6 of the AMBER key are conductors A2, pins 27 and D, and terminal 17 on the terminal strip for the J53033B unit.

24. You would press the WHITE request pushbutton, then the AMBER button, and finally the GREEN pushbutton to check the normal operation pattern.

25. You press a colored key for the second time to extinguish the associated colored lamp, or by pressing the subsequent colored key you can put out the preceding colored lamp.

26. 302A system maintenance is divided into inspections, performance tests, trouble location, and repair.

27. Individual components are proven good or bad by an operational analysis.

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28. Green workcards provide information for preventive maintenance performed while the equipment is operating.

29. The unit should be replaced, tagged, and sent to depot for repair.

30. Cables and receptacles are color-coded to insure correct mating.

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STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 OR NUMBER 2 PENCIL.

36254 04 22

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed*. Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

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Multiple Choice

1. (001) A modern key telephone system will ordinarily provide

   a. three to seven talking circuits distributed among five to fifteen stations.
   b. two to four talking circuits distributed among five to ten stations.
   c. three to fifteen lines distributed among five to fifteen stations.
   d. five to fifteen lines distributed among three to seven stations.

2. (003) In a key system, amphenol connectors are now used on

   a. call directors with EXCLUSION keys only.
   b. bridging terminals.
   c. connecting blocks.
   d. mounting cords.

3. (004) What purpose does the EXCLUSION switch on the 656 key telephone serve?

   a. Restores all PICKUP keys.
   b. Provides privacy for all lines.
   c. Provides the user with one private line.
   d. Permits all stations to have more privacy.

4. (005) A 565 telephone set has

   a. six keys (buttons).
   b. exclusion but no lamps.
   c. lamps but no exclusion.
   d. neither lamps nor exclusion.

5. (005) A 564HL telephone set has

   a. five pushbuttons.
   b. no speaker-phone control.
   c. four channels for communications.
   d. cutoff without the exclusion feature.

6. (005) Four channels, an EXCLUSION key, station busy lamp control, speaker-phone control, and plug-in cord can be found on which of the following telephone sets?

   a. 565EB.
   b. 565GA.
   c. 565HB.
   d. 565LD.

7. (005) Refer to figure 3 of the text. Determine which of the following telephone sets has four pushbuttons, yet does not have an EXCLUSION key.

   a. 544BB.
   b. 545BB.
   c. 564HB.
   d. 565HB.

8. (007) Prearranged key telephone units developed for a specific system are referred to as a

   a. PBX.
   b. package.
   c. central office.
   d. telephone station.

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9. (007-008) Which of the following KTUs provides dial selective intercom for a 200G7DC package?

a. 19175.
b. 400B.
c. 207C.
d. 202D.

10. (008) A 9-station intercom system requires which of the following?

a. One digit only for selection.
b. Two-digit dialing for selectivity.
c. Four master stations and five remote stations.
d. Five master stations and four remote stations.

11. (009) Which of the following design features permits faster, easier repair action of the 1A2 key system?

a. Flexibility.
b. Prewired systems
c. Miniaturized relays.
d. Plug-in line circuit cards.

12. (011) Which of the following 6A systems would you most likely encounter during OJT in your AFSC?

a. 200H18.
b. 200H9DC.
c. 200H18DC.
d. 200H36DC.

13. (012) Intercommunications system remote stations can

a. talk to other remotes.
b. talk to master stations only.
c. talk to both remotes and masters.
d. signal and talk to both masters and remotes.

14. (015-016) Which operated relay in a 1A1 key system causes the signal lamp to burn without flashing?

a. A.
b. R.
c. TO.
d. H.

15. (016) Which contact and operated relay in the 1A1 key system connects the incoming line to the station telephone talking circuit?

a. Contact 6 of relay H.
b. Contact B9 of relay A.
c. Contact M1 of the relay H.
d. Contact M12 of relay A.

16. (016) Which of the following units provide the winking lamp for a key system using 230B KTUs?

a. 232B KTU and KS-16171 network.
b. 232B KTU and interrupter.
c. 212B and 400B KTUs.
d. 222A and 222B KTUs.

17. (017) How many talk paths are provided by the 207CKTU?

a. 1.
b. 2.
c. 9.
d. 36.

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18. (017) If a subscriber desires to use his intercom line and lifts his handset, what relay or relays operate in the 207CKTU?

a. A.
b. B.
c. A, B.
d. A, B, C.

19. (018) The operated rotary magnet in the Dial Selective Intercom Unit causes

a. relay A to release.
b. the release magnet to operate.
c. the stepping switch to restore.
d. the stepping switch to operate and, in turn, to operate the ON switch.

20. (019) Which of the following digits operates the RL relay for the intercom circuit described in the text?

a. Tens digit 1.
b. Tens digit 2.
c. Units digit 9.
d. Units digit 2.

21. (020) In the 400D line circuit, at what potential is the idle CT capacitor maintained?

a. -14 volts.
b. -16 volts.
c. -18 volts.
d. +18 volts.

22. (021) The purpose of RT2 resistor is to

a. prevent release of the B.
b. reset the "B" release time.
c. control duration of time-out.
d. prevent false operation of time-out.

23. (023) Of the following 1A2 key system circuit components, which is *not* operated when the HOLD pushbutton is depressed?

a. Transistor Q3.
b. Relay A.
c. Relay B.
d. Relay C.

24. (025) The operating circuit of the A relay for the Dial Selective Intercom KTU used with the 6A key system includes

a. punching 13A.
b. punching 5A.
c. relay B.
d. relay L.

25. (025) What relays must be operated to complete the operating circuit of relay B1 in the 222A KTU?

a. Relays A and B in the 207C KTU.
b. Relay B in the 207C KTU and relay BY in the 224A KTU.
c. Relays BC, BC1, and CH in the 222A KTU, and relay B in the 207C KTU.
d. Relays L, TB1, and TB2, in the 222A KTU, and relay A in the 207C KTU.

26. (026) In an 18-station intercom system, which of the following numbers would you assign for transfer?

a. 2.
b. 4.
c. 8.
d. 10.

27. (027) Which of the following relays must operate for the lamps to flash for a key telephone installed in a 6A key system?

    a. Relays A and B in KTU 207C, relays B1, LS, L, and LT in KTU 222A, and relay M in KTU 232B.
    b. Relays A and B in KTU 207C, relays B1 and LS in KTU 222A and relay ST in the 232B KTU.
    c. Relays B1, TB1, TB2, L, LS, and LT in KTU 222A, and relay ST in the 232B KTU.
    d. Relays A, B, C, and T in KTU 207C and relay V in the 224A KTU.

28. (027) Relay LS in the 222A KTU operates because of

    a. a decrease in current as a result of operated contact M2 on relay BC1.
    b. an increase in resistance as a result of operated contact M2 on relay BC1.
    c. a decrease in resistance as a result of operated contact M2 on relay BC1.
    d. 105 volts alternating current being connected to its windings by contact M1 of operated relay TB1 and operated contact M9 of relay B1 in KTU 222A.

29. (028) Relay TB1 is the talking battery relay for which talking link?

    a. 1A1 key.
    b. 1A2 key.
    c. 6A primary.
    d. 6A secondary.

30. (029) The feature that prevents other subscribers from entering an existing conversation is called

    a. conversation isolation.
    b. optional cutoff.
    c. automatic cutoff.
    d. exclusion.

31. (031) Which of the following KTUs allows the idle station to be signalled while the secondary link is busy?

    a. 217A.
    b. 224B.
    c. 224A.
    d. 238A.

32. (031-033) An operated conference pushbutton does which of the following?

    a. Provides dial pulses to the 207C KTU.
    b. Provides negative battery to relays TB1 and TB2 in the 222A KTU.
    c. Makes direct contact with terminals for many stations, thus completing their talking circuits.
    d. Completes a relay circuit which, in turn, makes additional relay circuits, thereby resulting in signaling for several stations.

33. (032) Upon answering a conference call, the CH relay is released by the

    a. calling party.
    b. last answering party.
    c. first answering party.
    d. second answering party.

34. (035) Proper installation of a telephone station is best assured with

    a. tight control and limited discipline.
    b. simple instructions and few regulations.
    c. restrictive administration and reserved facilities.
    d. planning, coordination, and use of prepared cut sheets.

35. (036) Which of the following may destroy inside-type telephone cable?

a. Light.
b. Space.
c. Heat.
d. Rain.

36. (035) Which of the following are factors to be considered by a telephone installation supervisor?

a. Floor support, wall clearance, cable design, equipment placement.
b. Water quality, temperature control, plaster ingredients, and steel stress factors.
c. Temperature coefficients, frequency variations, electron velocity, and cable pressure deviations.
d. Conductor breakdown potential, power deviations, circuit variables, and fuse and circuit breaker reliability.

37. (037) Which of the following types of inside wiring cables is a standard "D" code cable?

a. 25-pair plastic.
b. 26-pair fabric.
c. 51-pair plastic
d. 76-pair fabric.

38. (037) How many colored binders will you find included in a 50-pair cable?

a. 1.
b. 2.
c. 3.
d. 4.

39. (037) Identify the pair of conductors that you will connect to terminals 3 and 4 on terminal strip B of a 230B KTU.

a. T and R for line 3.
b. L and LG for line 3.
c. L and LG for line 2.
d. A and A1 for line 2.

40. (038) When you are making an operational test of a 1A1 key system, you should test

a. one phone for all features, with other instruments of the system in use.
b. one phone for hold, incoming signal, dial, and intercom.
c. each phone, one at a time, for all features and service.
d. each phone for talk, receive, and dial only.

41. (038) Connecting the bells between tip and ring of a key system telephone results in what type ringing?

a. Metallic.
b. Selective.
c. Common audible.
d. Multifrequency.

42. (039) Which of the following lines normally returns dial tone to a key system telephone?

a. 1A1 intercom line.
b. A "HELD" line.
c. Power line.
d. A CO line.

43. (039) When a PICKUP key is depressed, you should be able to see a

a. dark lamp.
b. steady lamp.
c. winking lamp.
d. flashing lamp.

44. (041) Which of the following procedures is considered to be sufficient for checking a key system HOLD circuit?

a. Press the HOLD button.
b. Depress a PICKUP key and press the HOLD button.
c. Lift the handset, depress a PICKUP key, and press the HOLD button.
d. Plug in the power cord, release a PICKUP key, and press the HOLD button.

45. (041) Of the following relays, which provides power to the transmitter of a telephone in the 6A key system?

a. B1.
b. LS.
c. LTR.
d. TB2.

46. (042) Usually, an analysis of trouble symptoms discloses that

a. a component is open.
b. a device is short-circuited.
c. a specific unit is in trouble.
d. test equipment is not often necessary for key system maintenance.

47. (042) What type trouble will most often occur in relays?

a. Open windings.
b. Broken springs.
c. Shorted windings.
d. Contact maladjustment.

48. (044) The manufacturer's specification that allows for equipment deterioration current value changes prior to adjustment is the

a. inspection value.
b. adjustment value.
c. installation value.
d. readjustment value.

49. (047) Solderless connections made under pressure are provided with a

a. current-flow test set.
b. wire wrap gun.
c. multimeter.
d. TS-365/GT.

50. (048) The mimimum number of wraps required at a key system terminal for 22-gauge wire is

a. 7.
b. 5.
c. 4.
d. 2.

51. (049) Shorts at solderless terminals may be caused by

a. maladjusted relay contacts.
b. parallel resistors.
c. pigtails.
d. fuses.

52. (051) Information that must be known for planning an installation should include the

a. approximate distance of runs.
b. equipment voltage requirements.
c. annunciator construction and operating principles.
d. voltage readings at the many equipment test points.

53. (052) An interconnection sheet can provide maintenance information pertaining to

a. equipment changes.
b. connection changes.
c. repairman assignments.
d. tool and test equipment requirements.

54. (053) When installing and locating units, which of the following items would be considered as poor practice?

a. Placing units at specified locations when possible.
b. Placing wall-mounted units where they will not be a safety hazard.
c. Using extension cords when the power source is a great distance from the unit.
d. Always giving due consideration to the recommendations of the user.

55. (053) If you are to install two intercom stations that have a 50-ohm impedance limitation, which of the following approximates the maximum length of the circuit if you used 16-gauge conductors?

a. .5 miles.
b. 2 miles.
c. 1500 feet.
d. 6000 feet.

56. (054) Placing intercommunications and power cable close together often results in

a. induced noise.
b. induced moisture.
c. reduced security.
d. hum frequency shielding.

57. (054) When speaking into an intercommunications unit, how far should your mouth be from the front of the unit?

a. 6-18 inches.
b. 10-12 inches.
c. 12-18 inches.
d. 18-30 inches.

58. (055) External faults of an intercommunications system are normally corrected

a. after notifying the radio repair section.
b. by installer-repairmen.
c. with test equipment.
d. by radio personnel.

59. (055) The repairman's scheduled check of an intercommunication system should include what kind of check on the vacuum tuves?

a. Electrical check for shorts.
b. Physical check for cracks.
c. Visual check for dirt.
d. Operational check.

60. (056) As a telephone installer-repairman, what component will you be responsible for during the maintenance of an intercommunications system?

a. Solid-state device.
b. Vacuum tube.
c. Transformer.
d. Cable.

61. (057) What is the purpose of the TRANSFER key at the console positions?

a. To transfer the controller's radar.
b. To exclude the assistance controller.
c. To eliminate interference at the positions.
d. To transfer from wire circuits to radio circuits.

62. (058) Automatic signaling by lifting the handset from the telephone is provided in a

a. 1A1 key system.
b. 1A2 key system.
c. direct line telephone system.
d. automatic dial telephone system.

63. (059) The operated AMBER pushbutton in the operations van

a. extinguishes the WHITE lamp.
b. extinguishes the GREEN lamp.
c. operates a chime in the operations van.
d. operates an AMBER lamp in the approaching aircraft.

64. (060) The purpose of the request and acknowledgment circuit is to

a. aid the voice line communications.
b. acknowledge the status of the radar.
c. request assistance during aircraft landings.
d. identify phases of aircraft approach and landing.

65. (062) Which of the following cannot operate if its ASSOCIATE key is depressed while the RED lamp is glowing?

a. The GREEN lamp. c. The AMBER lamp.
b. The WHITE lamp d. The ON lamp.

66. (063) Which of the following circuits is not recorded?

a. PTT. c. COM.
b. PAR. d. RADIO.

67. (064) Relay TB1 for the 302 Switching Unit is installed in the

a. telephone relay rack at the control tower.
b. J53009CY-1 unit at the operations van.
c. J53033P-1 unit at the operations van.
d. equipment cabinet at the power van.

68. (066) The headset connections are changed from RADIO to WIRE circuits by depressing which of the following keys?

a. PICKUP. c. TRANSFER.
b. RELEASE. d. PUSH-TO-TALK.

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69. (066) Operating the TRANSFER key of a 302 Switching Unit to WIRE causes which relay to operate?

a. FR.
b. PL.
c. TB1.
d. WT1.

70. (067) Refer to foldout 7. Placing the two windings of relay CB in parallel will

a. increase the current of the circuit.
b. increase the resistance of relay CB.
c. release the central office equipment.
d. release the 302 Switching Unit equipment.

71. (067) What component short-circuits the controller's receiver during dialing?

a. 1 and 2 of WT.
b. 1 and 2B of RS.
c. 4 and 5T of RS.
d. 5 and 6T of RS.

72. (068) Which of the following relays provides dc for the transmitter at the controller's position?

a. WT1.
b. CB.
c. TB2.
d. TB1.

73. (070) Which relay starts the relay sequence for flashing lamps during an incoming call?

a. L.
b. FL.
c. FL1.
d. ST.

74. (070) How many keys are located in the J53033A, key and lamp unit?

a. 6.
b. 8.
c. 10.
d. 12.

75. (072) What action must be taken before using the request and acknowledge feature?

a. Operate the LP CONT switch.
b. Press the WHITE button.
c. Operate the ON switch.
d. Ground the "D" lead.

76. (072) Which of the following relay groups in the J53033B unit causes the AMBER lamp to function?

a. FL, A1, A2, A3, A4.
b. FL, A2, BO2, BR2, K2.
c. A2, BO2, K3, BR3, K4, A4.
d. A1, K1, A2, K2, A3, A4, K4, BO4, BR4.

77. (072) What relays in the J53033B unit are revealed to be operational if the RED lamp lights steadily following a performance test at the operations van?

a. A1, A2, K1, K2.
b. FL, A3, K3, BO3, BR3.
c. FL, A4, K4, BO4, BR4.
d. AC4, FL, A1, A2, A3, A4, K4.

78. (074) What device signifies to a second controller that the first controller is using the one-way voice circuit to the control tower?

a. A RED lamp.
b. A lighted PTT lamp.
c. An operated chime.
d. Playback from a recorder.

79. (075) In a three-position operations van, who is normally responsible for the radio communications?

a. Assistant controller only.
b. NCOIC of RAPCON unit.
c. Controller only.
d. All operators.

80. (075) During a radio transmission, the controller's transmitter

a. is protected from acoustical shock by a pad.
b. is shunted by contact 3B relay WT1.
c. has no impedance match.
d. needs dc.

81. (077) During routine maintenance, why is it unnecessary to check components individually?

a. They do not malfunction.
b. The user reports their condition daily.
c. Operational checks reveal their condition.
d. No individual components may be replaced.

82. (077) Information about performance routines is usually found on

a. pink workcards.
b. green workcards.
c. the equipment cabinet of the power van.
d. the telephone relay rack in the control tower.

83. (077) Assume that the first LINE lamp at assistant controller position 1 has failed to illuminate but that all other lamps are effective. What would be the logical solution for this condition?

a. Check the fuse panel.
b. Replace the LINE lamp.
c. Replace the ground strap that connects to all the LINE lamps.
d. Readjust the springs on the PICKUP key serving line 1.

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84. (078) To clean relay contacts, which of the following methods is least recommended?

a. Wiping.
b. Blowing.
c. Brushing.
d. Burnishing.

85. (079) What is the primary purpose for color-coding cables and receptacles?

a. For proper mating.
b. To identify circuits.
c. To insure proper fit.
d. For appearance only.

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